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MISSOURI GEOLOGICAL SURVEY

CHARLES R. KEYES, STATE GEOLOGIST

BIENNIAL REPORT

OF THE

STATE GEOLOGIST

TRANSMITTED BY THE

BUREAU OF GEOLOGY AND MINES

TO THE

39TH GENERAL ASSEMBLY



JEFFERSON CITY

TRIBUNE PRINTING COMPANY, STATE PRINTERS AND BINDERS

1897

MR. SPEAKER: Your Committee on Printing, to whom was referred the report of the State Geologist, begs leave to say that the same has been examined, and recommends that 1,500 copies be printed for the use of the members of the Legislature and the State Geologist.

R. P. THOMPSON, Ass't Chief Clerk.

30 .VIND
ANNOTUAO

LETTER OF TRANSMITTAL.

To the Thirty-ninth General Assembly of the State of Missouri:

GENTLEMEN—In accordance with the provisions expressed in section 5268 of the Revised Statutes of the State of Missouri (1889) the Board of Managers of the Bureau of Geology and Mines begs leave to lay before you the following report of the operations of the Bureau during the biennial period just passed. The Board has endeavored to carry out both the spirit and letter of the law governing the expenditure of the moneys appropriated for the investigation of the mineral resources of the State, and, holding always in view the greatest good to the greatest number, has tried to use these funds to the best advantage. The details of the progress of the work are fully set forth in the appended report of the State Geologist. The plans therein formulated for the execution of future work heartily commends itself to the approval of the Board, which has every confidence that the State receives full value for every dollar thus expended in acquiring knowledge and in disseminating useful information regarding our mineral wealth and natural resources.

The following is an exhibit of the expenditures of the appropriation made by the last General Assembly :

Salaries	\$8,015 50
Special and temporary assistance	1,909 08
Railway fare, wagon hire and subsistence	918 02
Printing and binding reports	8,096 03
Freight, express and postage	618 63
Supplies, books, etc	440 59
Balance	11
	<hr/>
	\$20,000 00

The Board of Managers is fully convinced of the great importance to the people of the State of the continuance of the investigations on a liberal basis and believes that the State will be amply repaid for all expenditures in the future which will enable the work already begun under such auspicious circumstances and now so well advanced, to be carried on to completion. While it is fully recognized that a much larger amount of money annually available would allow the work to go on just that much faster and get the results before the public just that much sooner, it is thought that the continuance of a moderate appropriation will enable the investigations to go on uninterruptedly on the same satisfactory plan as heretofore. The Board therefore unanimously recommends to you the propriety of the following appropriations for the next biennial period :

For maintenance (2 years)	\$15,000
For printing reports (in press or ready for the press)	8,000
For printing reports (completed during biennial period)	7,000
	<hr/>
	\$30,000

The appropriation asked for maintenance is small, and is the minimum amount upon which the investigations of our mineral and natural resources should be carried on.

The amount requested for printing is very urgent, and is not only desirable but necessary, if the results are to be given to the public promptly. Part of this is for the usual publishing of the reports that will be finished and ready before the end of the biennial term ; the estimate is low. The other part is for the printing of very important and valuable reports which have been completed for some time, and which should not be longer delayed.

In conclusion, your careful consideration is invited to the detailed report of the State Geologist herewith submitted.

WM. J. STONE,

President of the Board.

FOURTH BIENNIAL REPORT
OF THE
STATE GEOLOGIST
BY
CHARLES ROLLIN KEYES.

BOARD OF MANAGERS.

HIS EXCELLENCY, WILLIAM J. STONE, GOVERNOR OF MISSOURI, JEFFERSON CITY

Ex Officio President of the Board.

DR. J. H. BRITTS.CLINTON

HON. W. O. L. JEWETT....SHELBYNA

PROF. E. M. SHEPARD, DRURY COLLEGE.....SPRINGFIELD

PREFATORY LETTER.

MISSOURI GEOLOGICAL SURVEY, }
JEFFERSON CITY, Dec. 31, 1896. }

To the President, Governor William F. Stone, and the Honorable Members of the Board of Managers of the Bureau of Geology and Mines:

GENTLEMEN—I have the honor to transmit herewith a report of the progress made by the Missouri Geological Survey during the biennial period just ending, and to remain, with great respect,

Your obedient servant,

CHARLES R. KEYES,
State Geologist.

BIENNIAL REPORT OF THE STATE GEOLOGIST

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INTRODUCTORY.

During the biennial period just passed the work of the Bureau of Geology and Mines has made very satisfactory progress. The advancement of the Geological Survey of the state has more than come up to the expectations of the plans laid out at the beginning of the term. There have been no radical departures from the general policy adopted at the time of the reorganization of the Survey and as carried out in the latter part of the previous biennial period. The minor changes which have occurred have been chiefly to secure better articulation of the different branches of investigation in progress.

The prediction of the previous biennial statements in regard to the completion of reports have been fulfilled in the publication, during the biennial term that has lately closed, of four volumes of the regular series of memoirs. These publications comprise ten different formal reports, besides several scientific and economic papers on special themes. Of several important lines of work which are so far completed as to permit special reports to be issued there may be mentioned the clays, certain phases of the building stones, the general foundation for a detailed consideration of the soils, the origin of the physical features of the state, and the areal mapping of several districts of more than usual importance. Particular mention is made of each of these in another place.

Notwithstanding the manifold and ever increasing duties connected with the work of administration and the large amount of time and effort necessary in the proper editing of the manuscript reports, and in the proof-reading, all of which cannot be left to any one else but the person in charge, there remained a much larger proportion of time for field work than was thought possible in the beginning, and the acquisition of results regarding the special investigations has been correspondingly advanced. The work accomplished by the different members of the geological corps is considered in detail elsewhere.

The main energies of the Survey have been directed towards finishing up work which had been previously begun, and which was already in a more or less advanced stage of completion. However, the new work undertaken has not been inconsiderable, and much new and important information has been obtained.

The reports on lead and zinc were completed, and distributed during the first half of the period. The review of the fossils was likewise distributed at the same time. Three other volumes printed during the period were also sent out and a fourth is already printed, and a fifth partly so.

The advancement made in the various branches on which special effort was directed to insure a speedy completion has been fruitful of very important results, some of which were hardly expected to be secured so early in the investigation. Prominent among these may be mentioned the line of inquiry instituted regarding the coal deposits of the state, the extent and occurrence of the crystalline building stones, and the determination of the arrangement and areal extent of the formations of the Ozark region, which includes a large part of south Missouri.

During the biennial period Federal topographic mapping has been revived in the state, with the special object in view of providing much more accurate base maps than now exist, on which to place the geological features. It is hoped that the state may bring about conditions whereby this important work can be pushed more rapidly, in the same way that it is being done in other states, notably Massachusetts and New Jersey.

The extent to which the reports of the Geological Survey are used practically, and referred to, is appreciated by comparatively few persons. It seems worth the while at this time to mention some of the ways in which the information published by the Survey is utilized, because it is considered authoritative. Coming from official and disinterested sources the statements carry far greater weight than they could possibly in any other way. Abstracts of the reports and even whole chapters on special points are reproduced in the various trade journals, and in sketches of the mineral resources of the country. From time to time the scientific and engineering journals of all countries call attention to the progress of the work. Recently the principal text-book in this country, on ore-deposits, used both facts and illustrations from the Missouri reports, and a similar work published in France likewise depended upon the same source of information. Still later a large work on the mineral industries of the United States availed itself of the data collected by the Survey. Two new geographies which are to be used extensively in Missouri schools were recast and the entire portions pertaining to the state remodelled upon lines suggested by the reports issued by the Missouri Geological Survey.

These are only a few of the instances in which the Survey disseminates useful information regarding the mineral wealth of the state

and advertises the resources of the commonwealth. In this connection no mention is made of the many other ways in which the same thing is being accomplished for the state by the survey; or, of the many letters of inquiry continually coming not only from all parts of the state but from all parts of the whole country and from abroad.

The warm appreciation of the efforts to carry out to completion the investigations begun, which is everywhere met with, is not only extremely gratifying but it is a matter of congratulation. The great interest now shown in the examination of the natural resources is not wholly confined to the people of the state. There are probably as many persons living without the borders of Missouri as there are within them, who are keeping themselves informed as to what is being done by the Survey. Indeed, the work has met with as universal favor and appreciation abroad as at home.

GENERAL PLAN OF ORGANIZATION.

In a former report the objects to be attained for the State were fully set forth, and the organization of the work for completing the geological survey was also given in detail. Only a brief outline of the general plan of operation needs therefore be considered. As will be seen at a glance the entire plan of the Survey is practical in its aim. While thoroughly economic in all its aspects, the work is so arranged that it may be carried on in a manner perfectly systematic and scientific. At all times the investigations are conducted in a way which, it is thought, will best serve the interests involved.

Ever since its first organization, the Missouri Geological Survey has come to direct its energies more and more to the investigation of the mineral wealth of the state from the standpoint of the utilitarian. Recently strong efforts have been made to concentrate the work still further.

From the beginning, two classes of work have been recognized. One is rather general in its character, the other more specific. The first is denominated subject work; the second areal work. With the first it is the practice to take up each particular topic, as coal, clay, iron, lead, zinc, or soil, and to consider the deposits as a whole for the entire state. In contradistinction, areal work has for its object the treatment of all useful mineral deposits of limited districts, as a county or other convenient area, special attention being given to the local details, and to the accurate mapping of the different geological formations. In its main features this dual arrangement of the work has been the policy of the Survey from the start, though modifications in many details have taken place from time to time, as the changes in

conditions necessitated and as the enlargement of the scope of the work demanded. A third class of facts might be properly grouped under the head of statistics; while the fourth line of work pertains to the publication of all results.

SUBJECT WORK.

Subject work is of first importance in the investigation of the natural resources of a region, for the reason that the results as they are given to the public satisfies a wide demand for information concerning the existence, mode of occurrence and properties of the various mineral substances. Deposits are not limited by political boundaries. Each kind of soil, each kind of mineral, clay, or other natural product dug from the earth, belongs to some particular geological formation; that is, it is found on some horizon, at some level, more plentifully than at others. Thus, one formation is abundantly supplied with coal, another with the ores of zinc and lead, a third with materials for the manufacture of cements, and others with still different substances of economic value. Each is found in a particular geological zone, and rarely or very sparingly elsewhere. Only within certain districts would search for a given substance be successful; outside of these areas no amount of prospecting would ever disclose the material sought.

In obtaining information concerning each particular mineral substance, the entire subject must be carefully considered. At the outset a clear understanding of the geological structure of the rocks containing it is of prime importance. The localities where each occurs require description; the arrangement, relations and extent of the deposits must be defined; the origin and the properties discussed; the accessibility and values determined; the uses of the substances, the nature and status, both present and probable future of the different industries fully considered. A complete report on each special subject is therefore comprehensive in character and concise in statement. This work cannot be weighted with the details of only local interest, as this would extend the account far beyond the space that could be allotted to it. Information of an entirely local character must be recorded largely on maps or described in accounts of areas.

In the beginning, then, subject work occupies a position more prominent than does the areal work in dealing with all of the useful mineral substances found. It necessarily includes two classes (1) the principal topics, which are the larger subjects, each requiring a very considerable period of time to finish, and (2) the subordinate subjects, which comprise numerous minor points. The former, are taken up

first. While they are being investigated facts are continually accumulating in regard to the collateral subjects which, with a little special attention later, are ultimately brought together, forming valuable additions to what is already known concerning the resources of the state.

The advantages of having the work done according to topics are numerous:

1. Since particular mineral substances, as already stated, are rarely confined to single counties, but are usually distributed over several and sometimes many such districts, it is necessary to investigate each kind of deposit in its entirety. It may then be told with certainty how, and to what extent, the several locations will be benefited by the development of such minerals.

2. The general discussion of the properties, uses and magnitude of each deposit may be taken up, and the results published long before all of the work in the counties containing the particular substances can be furnished.

3. In order that lasting results may be obtained more or less work of a general character is always necessary for the intelligent interpretation of the phenomena observed in any one county and to connect them with those seen in neighboring districts.

4. The investigations may be made by experts or specialists in the different lines. The results accomplished are therefore much more satisfactory, more accurate, and far more valuable than if obtained in any other way. Further, much less time is required and the cost is consequently very much less.

5. Since most people are engaged in one industry only, the information which interests them most is brought together. The miner wishes to be informed about coal, the quarryman, architect or engineer seeks good building-stones; the brick-maker or clay-worker desires something regarding the properties and adaptabilities of the different clays; each wants to know in regard to his special field and cares little or nothing about the others.

AREAL WORK.

In area work the economic resources of particular and limited districts receive consideration. Detailed information of a local character is taken up; the present and possible future developments of the mineral wealth are set forth. Its direct purpose is to meet the constant and ever increasing demands for trustworthy information in regard to given localities. The desire to know about the mineral products of each particular neighborhood is so general that full details are required

concerning every substance which is or is likely to be of value to the land-owner or occupant of the district. Probably one-half of the people of the State seek this local information.

Local information regarding limited districts is imparted in three ways : first, by descriptions and sections ; second, by illustrations, and third, by maps. At least three-fourths of the geological facts that are obtained are recorded cartographically. In consequence, therefore, a modern geological map is a graphic and concise summary of a vast amount of useful information. In addition to an accurate representation of the ordinary geographical features, as in the best atlases, a properly constructed geographical map records very much more. On it are indicated, within a few feet, the elevation above the sea-level of every point within the borders of the area ; the drainage basins and the water-powers ; the distribution and limits of the different geological formations, the various kinds of ores, building-stones, clays and all minerals of economic value contained in the several beds, and the best places for obtaining all these substances. The map also forms a reliable soil index, which, with some additional explanation, serves also as a guide to the distribution of the forests and plants generally.

In mapping, all the districts of the state cannot be treated alike. Some places require far more work than others, either on account of the great importance of the mineral deposits or the natural difficulties caused by the ruggedness of the country. Other regions, as those which contain the principal iron ores, the most valuable lead and zinc deposits, or particular beds, require in the beginning accurate relief maps. Places where the immediate mineral wealth is not so great, do not need elaborate topographical maps. At the present time it is not advisable, nor even if it were desirable, would the resources of the Survey permit this great extension of its work, without a very considerable enlargement of its powers. The inquiries must go on as rapidly as is consistent with good and accurate results. In order of their importance must the various districts be mapped, and in proportion to their mineral wealth must the details be recorded.

The preparation of a full set of maps of this kind is not the result of a few day's effort, but is the labor of several years. As a part of the investigation into the economic resources, there is in contemplation a series of maps which shall embrace for every section of the state all of the information already mentioned. Some of them will be somewhat general in their character and will accompany the different special reports. Other will be more detailed in plan and will cover given counties or such other areas as may be thought desirable.

Among some of the last named the folio plates accompanying the sheet reports are examples. In the construction of maps showing the distribution and occurrence of mineral substances it is of prime importance that the surface relief should be depicted in a readily intelligible manner. A map which represents most closely a perfect miniature of the surface of the region is far superior to any ordinary atlas. It is invaluable not alone to the trained geologist, but it is about the only practical way by which the average citizen is able to comprehend at a glance the actual resources of a district. In proportion as the exactness with which the diminutive representation approaches the actual surface, in the same proportion does the usefulness of the work increase. The modern methods of making maps are so far advanced over those of a quarter of a century ago that there is now no excuse for any community to be without the best.

Briefly, then, a properly constructed geological map of a district, not only locates accurately the various mineral deposits, but also represents the prominent landscape features by which the locations may be more readily recognized. A relief map also serves other purposes. Upon it may be based models of the more important districts which are to be taken as characteristic of much larger areas, and which are to represent in a graphic manner the structural arrangement and relations of deposits. Eventually a relief model of the entire state may be constructed on a suitable scale. Besides the purposes mentioned it would afford one of the most instructive objects for presenting to the pupils of schools the geographic features of their state. With the wide introduction of the new methods of teaching geography the value of such aids cannot be overestimated.

COLLECTION OF STATISTICAL MATTER.

While not strictly a theme of geological investigation, the collection of statistics concerning the work and output of the various industries dependent upon the natural resources of the state is generally expected to come properly within the scope of the geological survey. By means of this information accurate comparisons of the yearly progress made may be instituted. The figures are obtained in two ways—partly through printed circulars and accompanying blanks sent to the respective trades, and partly by personal visits of different members of the geological corps, in course of their other investigations. All information is considered as strictly confidential; and the tables of comparison are arranged by counties in such a way as not to disclose the details of any individual business. The unusually favorable opportunities offered by the Survey's facilities makes this class of

figures of particular value, especially in the case of those industries about which little is now done in this direction.

PUBLICATION OF RESULTS OF INVESTIGATIONS.

No feature in the investigation of the natural resources of the state is of greater importance than the placing of practical information in regard to the various deposits before the people as rapidly as it is possible to get it into a measurably complete form. But in making public the results of the geological survey of the state, the common practice of transcribing field notes and of making incoherent preliminary reports on different subjects has been wholly discarded. The general plan of field work is in the beginning arranged, as far as it is possible, so as to accord with the ultimate presentation of the results in printed form. Hence, two general divisions are recognized in publication, as in the field work, though their distinctions may not be so obvious at first glance.

The adoption of a single series of publications, uniform in size, in general style and in binding, will, it is thought, do away with much of the inconvenience and many of the objections arising from the various ideas of different individuals as to what is the most appropriate manner of getting out work of this kind, or from an adaptation to the particular facilities possessed by various printers. As nearly as possible each volume contains in the neighborhood of 500 pages, besides the necessary illustrations and accompanying maps. There is, however, one exception—the final state atlas. Although numbered consecutively, the separate volumes are in no way dependent upon any which have gone before or any which may follow. Each may therefore be regarded as complete in itself. This plan enables one volume to be devoted to one topic, and another to another. It permits the placing of results before the public as rapidly as the investigations are completed, without long and vexatious delays. A particular deposit extending into a number of districts may thus be studied thoroughly and a report made without waiting for the entire work in the several counties to be finished. Similarly, different counties or areas may be reported upon before any special deposit is examined over all the state. In some cases the work requires a very much longer time to complete than in others; and it is often very desirable, especially with the larger subjects, that some information be made accessible before the appearance of the final report. When the work of any particular topic has reached a more or less advanced stage of completion some special

phase of the subject may be briefly discussed and emphasized in advance, but the article is always made complete in itself, depending neither upon anything which has been issued nor which is to be published.

The publication of results is also brought about in two other ways: (1) through the newspapers, and (2) through scientific and trade periodicals. To the newspapers are sent accounts of new discoveries and carefully prepared articles of general interest on particular deposits of certain districts. Information of a preliminary character is thus also given to the public months before the entire work is completed and published. At the same time popular interest is enlivened and a stimulus given to local investigations. Topics of unusual geological importance are frequently discussed in papers which appear in the various scientific journals.

THE INVESTIGATIONS COMPLETED.

As the inquiries into the natural resources of the state come to be completed along the various lines all the information obtained is brought together into a compact and presentable shape and published. The work on these branches is for a time at least given a subordinate place, and the energies of the survey are turned in other directions, into those fields most urgently demanding attention. The special branches upon which reports have been made are briefly considered below and the detailed contents of each volume are given farther on.

EXAMINATION OF THE IRON ORES.

No one thing demonstrated more clearly the importance of Missouri as a region of vast mineral wealth than the setting before the world, as one of the principal results of the first systematic work done on the geological features of Missouri, the great value of the iron deposits of the state. Considerable attention was subsequently paid to the same subject at different times, but the recent decline in the iron industry of the state has again awakened special interest in this topic, and has hastened a revival of the inquiry which was abandoned more than twenty years ago.

Briefly stated, the aim of the work recently accomplished was to establish districts in which iron ores were most abundant, to ascertain the exact character of the deposits, in order that prospecting might be done in the most intelligible way, and to determine whether or not the conditions were favorable to the establishment of local smelting works. The results have been more than gratifying. In carrying out

the work, the greatest amount of time was given to points practically untouched, though controlled by the promise of iron ore in a given district, and the remaining time was distributed as seemed best to serve the objects of a general report upon the iron ore of the whole state. In a former account considerable attention was paid to the limonites on the Belmont branch of the St. Louis, Iron Mountain and Southern railroad, and on the Middle Osage river. The ore bodies there pointed out are yet hardly touched, especially the Osage deposits, and attention has therefore been called to these localities as possible ore fields. The whole tier of counties along and immediately above the Arkansas border, from and including Stoddard county to Taney, was hardly touched. There are ten counties and only six localities reported. Recent work shows this field to be at least as productive as any in the state, and, consequently, much time has been devoted to it. Even the most conscientious effort to locate every outcrop of iron ore would in the end fail in the present state of development of the country. Enough work has been done to prove that limonite ore exists in sufficient quantities to warrant the erection of local furnaces for its smelting, and that other conditions are favorable for such an enterprise. This fact has been enlarged upon in the report.

The location of ore deposits, means, however, more than the mere fixing of these outcrops alone. One outcrop points certainly to others, neither now located nor reported, and the particular aim of the work done has been to point the direction in which others may be confidently looked for.

The outcome of the investigation has been the examination of the iron ore deposits in forty-three counties. It has included a determination of the general extent of iron ores in the various districts, an inquiry into their origin, an outlining of the general conditions of their distribution, a consideration of the qualities of the various ores, for which purpose a number of samples were collected, of which chemical analyses were made. In addition to fully discussing these topics, the report, which embraces nearly 400 pages, describes all the more important occurrences, and conveys recommendations regarding the best means for their development.

This report was completed and published four years ago. Some conception of the great extent and importance of the industry may be gained from the statement that the total production up to that time was over 7,715,000 tons, having a valuation of more than \$30,000,000. The growth of the output up to the year the report was made, 1892, is

perhaps more adequately represented by the following diagram (figure 1) taken from the report.

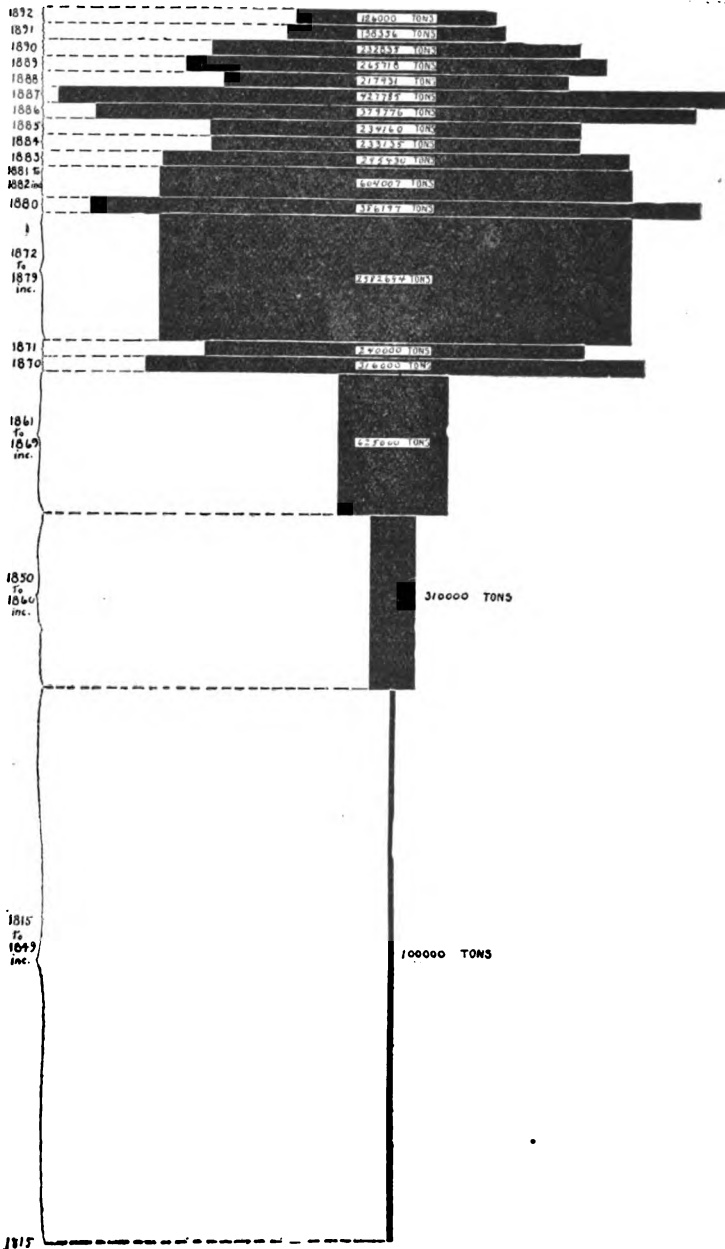


Figure 1. Growth of the Iron Production in Missouri.

The counties in which workable deposits are found and the kinds of ore represented in each are indicated in the accompanying diagram

MISSOURI GEOLOGICAL SURVEY

CHARLES R. KEYES, State Geologist

SKETCH MAP

OF

MISSOURI

SHOWING THE KINDS AND DISTRIBUTION, BY COUNTIES,
OF THE

IRON ORES

1897

LEGEND

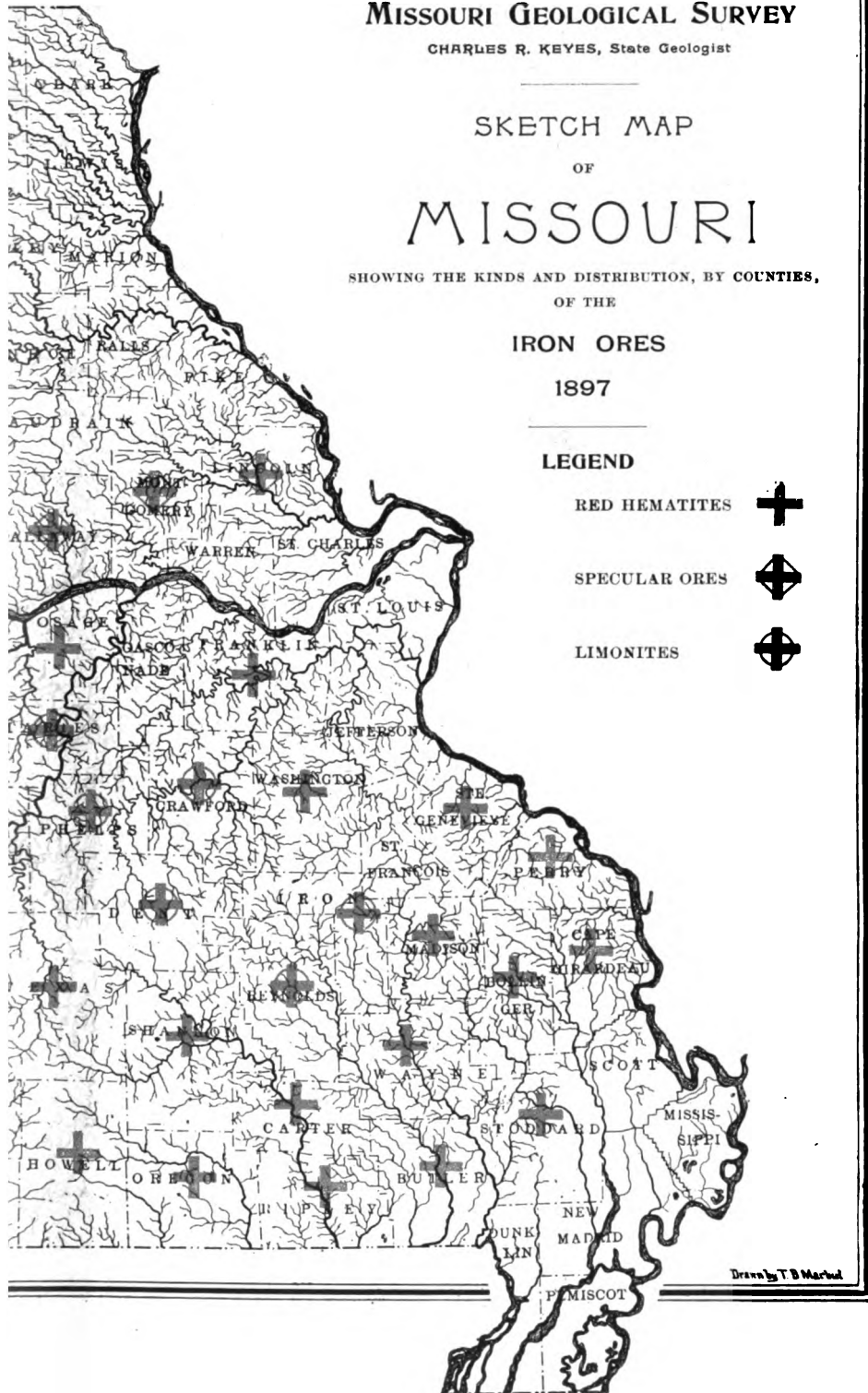
RED HEMATITES



SPECULAR ORES



LIMONITES



(plate 1). The counties in which detailed examinations were made are as follows :

Dunklin,	stone,	Christian,	Wright,
Mississippi,	Lincoln,	Pettis,	Douglas,
Howell,	St. Clair,	Iron,	Benton,
Ripley,	Morgan,	Lawrence,	Callaway,
Carter,	Pemiscot,	Osage,	Crawford,
Ozark,	Scott,	Hickory,	Dade,
Reynolds,	Stoddard,	Barry,	St. Francois,
Butler,	Bollinger,	Cooper,	Monroe,
Randolph,	Washington,	Cedar,	Maries,
Dent,	Texas,	Cole,	Henry,
Camden,	Wayne,	New Madrid,	Greene,
Franklin,	Taney,	Ste. Genevieve,	Montgomery,
Phelps,	Laclede,	Oregon,	Morgan,
Pulaski,	Madison,	Cape Girardeau,	Miller.
Jasper,	Gasconade,	Shannon,	

In further carrying on the work on the iron ores of the state the efforts of the survey will consist largely of systematic and detailed mapping in the iron ore regions, so that the distribution of the ore bodies, as well as the other surrounding conditions, may be shown in greater detail.

THE ANALYSIS OF THE MINERAL WATERS.

The results of the examinations far exceeded all expectations. The character of the waters and the extent of the improvements around the various springs have been appreciated by comparatively few persons. As stated in the report on this subject, the investigation of the mineral waters of the state was one of the first subjects to engage the attention of the present survey. Missouri, although not in possession of many handsomely improved resorts whose waters are of such wide reputation as to attract many visitors from abroad, has yet a great number of mineral springs, many of them of undoubted medicinal value, which are patronized by citizens of the state. The majority of people are unable to avail themselves of the cures of the well-known but distant resorts, and hence have recourse to what is provided at home. The investigation and the preparation of this report were hence undertaken principally for the following reasons: (1) to determine the composition and character of the waters and their values as compared with other waters which have acknowledged medicinal virtues; (2) to furnish an exact and full statement of the results reached, particularly for use of physicians; (3) to supply certain suggestions for the guidance of the citizens of the state in the use of these waters; (4) to make the fact of the existence of these waters authoritatively and widely known with the object of interesting others in developments and improvements at the different localities.

The results of the inquiry have been to give a full explanation of the origin, composition and therapeutics of the various mineral waters ; to discuss the different kinds found within the limits of the state, and to describe fully all the springs and wells. The report is embraced in one volume of 280 pages, with 23 plates of illustrations.

The distribution of these mineral springs is shown on the accompanying sketch (plate II). The counties included are :

Nodaway,	Saline.	Audrain,	Macon,
Worth,	Pike,	Cedar,	Randolph,
Mercer,	Johnson,	Perry,	Boone,
St. Louis,	Jasper,	Howell,	Kalls,
Madison,	Davless,	McDonald,	Callaway,
Barry,	Clinton,	Phelps,	Laclede,
Vernon,	Clay,	Barton,	Pettis,
Lewis,	Benton,	Lawrence,	Howard,
Monroe,	Jackson,	Livingston,	Cass,
Newton,	Henry,	Carroll,	Cooper,
Camden,	Jefferson,	Charlton,	Polk.
Morgan,	Marion,	Adair,	

THE WORK ON THE FOSSILS AND GENERAL STRATIGRAPHY.

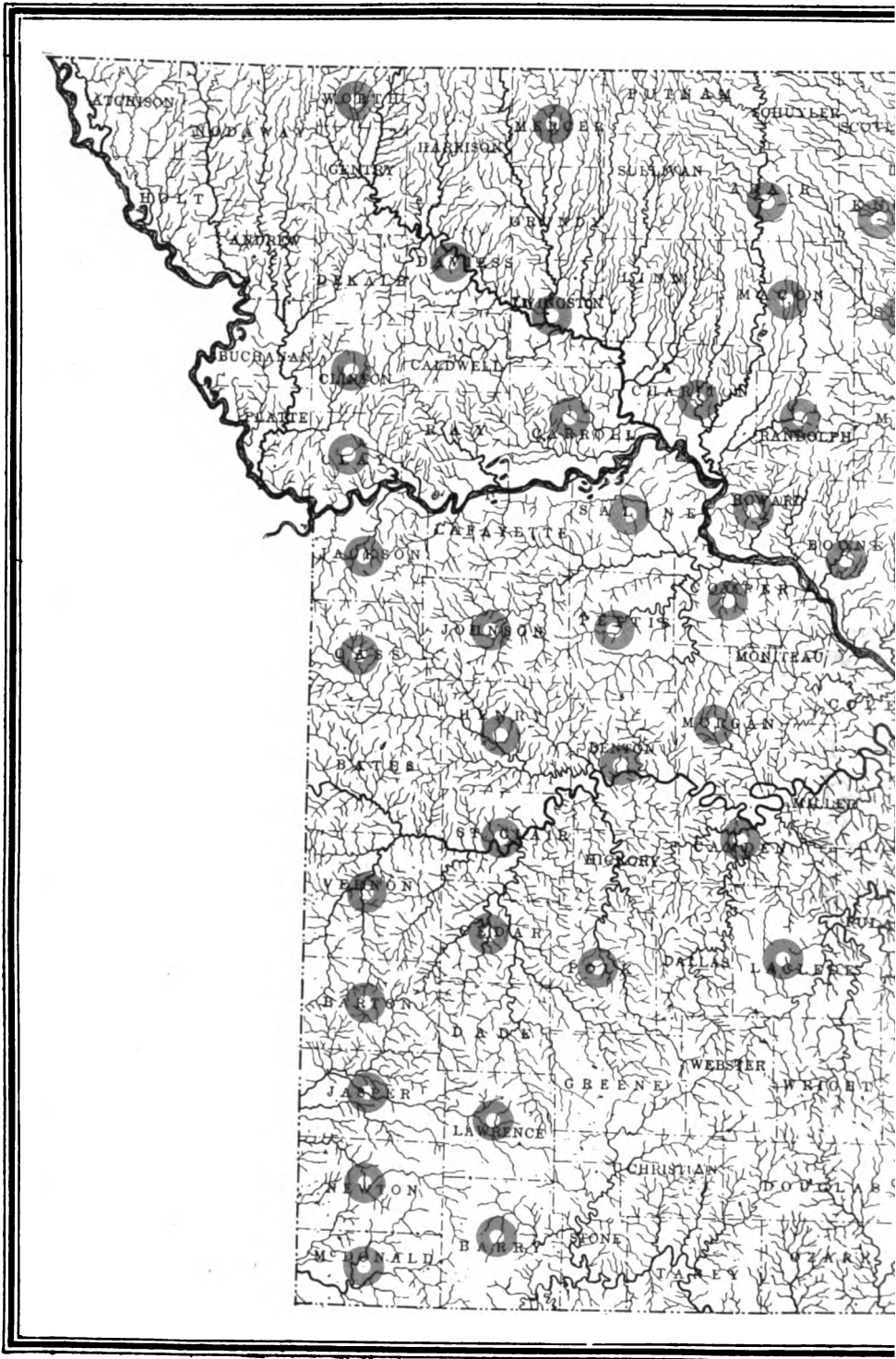
As a foundation for general as well as detailed stratigraphical investigation, which is an integral part of all geological work carried on in the state, the organic remains known to occur in the different rocks were carefully and critically examined. In many cases beds whose exact age and position were unknown or imperfectly understood were determined ; in many other cases the areal limits of geological formations were more accurately made out. A special phase of the subject which was always kept prominently in the foreground was what had been actually described previously, and where the descriptions or illustrations had appeared.

In the consideration of the fossils there was taken a radical departure from the usual reports on the subject of paleontology, in that an attempt was made to make it as strictly economic in its bearing as possible. Instead of giving new names to an endless number of forms, accompanied by long technical descriptions, it has been the aim rather to avoid them so far as possible. The economic value of fossils is commonly overlooked. Ordinarily these remains of ancient life are regarded merely as curious ; to the specialists the interest in the old organisms is wholly scientific ; but by him who is fairly well acquainted with their character and who is engaged in practical geological work, the rocks are read as a printed page. One of the best established facts of modern geological science is that there is an intimate relation between all mineral deposits and the surrounding rocks ; hence the age of particular beds becomes an important factor in the early at-

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MISSOURI GEOLOGICAL SURVEY

CHARLES R. KEYES, State Geologist

SKETCH MAP

OF

MISSOURI

SHOWING COUNTIES IN WHICH HAVE BEEN ANALYZED THE

WATER

MINERAL WATERS

1897

LEGEND

MINERAL SPRINGS



Drawn by T.B. Marshall

tempts to develop new mineral districts. These inferences rest upon one of the cardinal principles of geology, in that the geological sequence of strata is determined most rapidly by the remains of life contained. Thus, in reality, fossils are labels on the rocks.

The widespread desire which has existed for many years among certain classes of citizens who are interested directly in advancing the mineral development of the state has created a strong demand for accurate accounts of the organic remains found in the rocks of the region. This demand is becoming more and more urgent in the light of the fact that fossils have such a distinct economic importance in the determination of the age of useful mineral deposits, and hence serve as the most trustworthy guides known in the further development of the natural wealth of a region. In the attempt to satisfy properly the calls arising from the work of this character it has been the aim to present in a comprehensive report, as briefly as possible: (1) an index to the fossils of the state, through means of which forms now known to occur within the limits of the region under consideration may be recognized readily without recourse to great libraries; (2) a list of the works pertaining to Missouri fossils, in which is brought together all that has been written on the subject and which is now widely scattered and practically inaccessible; (3) a concise summary of all that has been done up to the present time in this branch of science so far as it pertains to the state; and (4) a guide to a more comprehensive study involving the solution of problems now more or less obscure concerning the arrangement and relations of the various strata. In short, it is a hand-book of the fossils of the state, adapted to the use of teacher, student and layman alike.

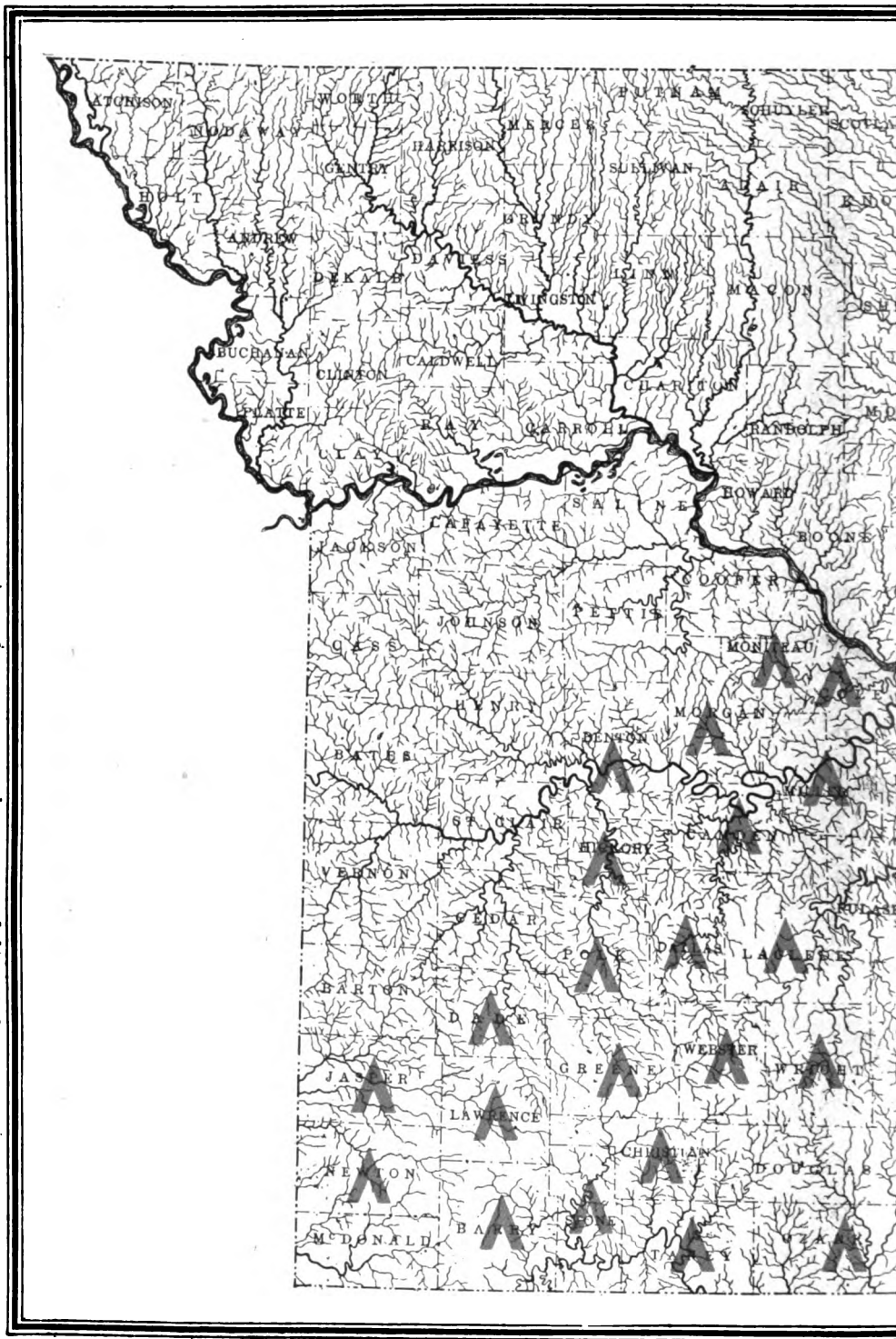
The general plan of treatment of the different species enumerated has been to give under each a more or less complete bibliography, by reference to which additional information or good illustrations of the forms not here figured may be found. In the diagnosis it has been the aim to give a rather full description of some leading representative of each genus, accompanied by a suitable figure, and to make the sketches of the other members of the group brief and in a great measure comparative. By this way of dealing with the subject it is thought that the characterizations of all the species will be sufficiently ample for intelligent comprehension, and for the particular uses to which the work will be put. At the same time the bulk of the report will be reduced very greatly—to one-fourth, at least, of what it would otherwise have to be. The horizon and some of the leading localities of each species are also given. The matter of localization has had to be rather general, allusion being made to the nearest post-office usually

or in a few instances, as when the fossil is common and the distribution wide, merely to the county. As a farther help there has been appended a stratigraphical catalogue which is intended for ready reference, and a synonymic indexical list of all the names applied to Missouri species. With the many natural difficulties to be taken into consideration, it is easily understood that from a geological or biological standpoint, any stratigraphic tabulation of the fossils of the state must necessarily be very incomplete for years to come, and must long lack uniformity in the number and kind of organisms assigned to each horizon. Nevertheless, in the present condition of knowledge there is peculiar economic importance in a special arrangement of the forms known at the present time to occur within the limits of Missouri, or on her borders, according to the strata in which they are found. With general geographical distribution known by reference to the colored geological map, the fossils which may be expected to be found in any locality in the state, may be quickly referred to without the labor of going through the whole report to pick them out. The fossils, forming as they do, labels to the deposits of commercial value, put a ready and inexpensive means in the hands of even the most inexperienced for determining what minerals of economic worth are to be sought for in the particular neighborhood and what are not to be expected.

The report is in two parts containing altogether over 600 pages and 56 plates, besides a revised geological map of the state. That its scope is fully appreciated and that its appearance is timely is clearly indicated by the fact that the demand for these volumes has exceeded those on any other one branch of investigation.

INVESTIGATION OF LEAD AND ZINC.

The increasing importance of the lead and zinc industry of Missouri made this branch of mining the first line of investigation undertaken by the survey after its organization. In the beginning co-operation between the Federal and State geological surveys was arranged for, the efforts of the former being directed chiefly towards the determination of the source and mode of origin of the various ores, and the activities of the latter being employed in detailed inspections of the mines opened and examinations of the deposits and regions which were thought to afford favorable conditions for future development. As, however, the work of the National survey was never completed so that it could be published, this branch of the investigation was also undertaken by the State survey not only for the southwestern part of the state where the earlier studies were made but for the central and southeastern districts as well.



MISSOURI GEOLOGICAL SURVEY

CHARLES R. KEYES, State Geologist

SKETCH MAP

OF

MISSOURI

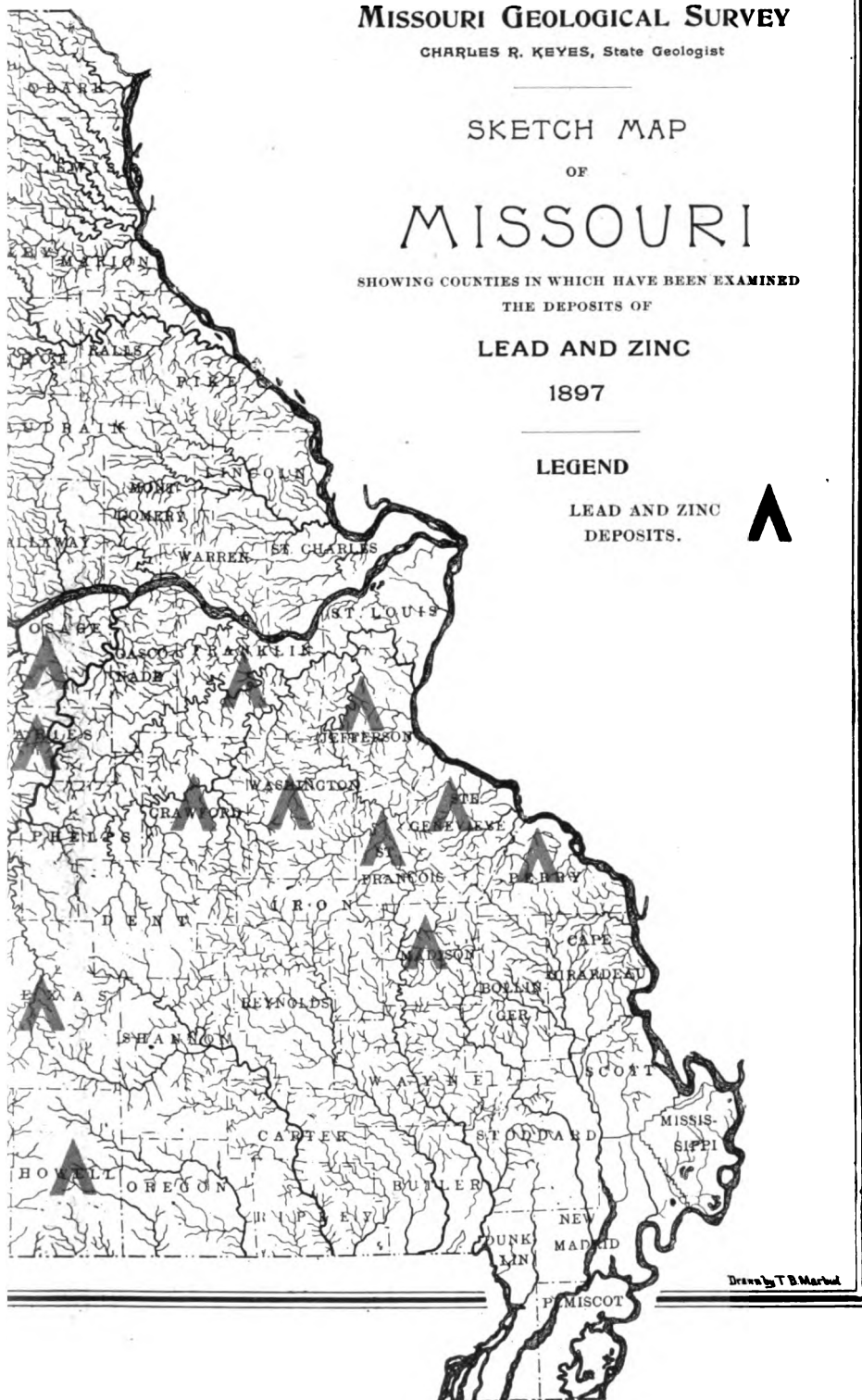
SHOWING COUNTIES IN WHICH HAVE BEEN EXAMINED
THE DEPOSITS OF

LEAD AND ZINC

1897

LEGEND

LEAD AND ZINC
DEPOSITS.



As is now generally known, lead and zinc constitutes Missouri's most prominent mineral products. The real importance of these metals is further comprehended when it is known that as a producer of the first named ore the state ranks second among the states of the Union, and of the second metal first, supplying more than two-fifths of the entire amount of the mineral in the United States.

In bringing together the great mass of information which accumulated in the course of the investigations three distinct phases of the subject were presented. The first was a comparison of the industry as carried on in other parts of the country and in other countries of the world with the development attained in Missouri. A second inquiry was into the development of mining in the state and the geological association of the ores. The third included a consideration of the local details.

The three-fold scheme is preserved in the report, which forms two large volumes, comprising nearly 800 closely printed pages, 40 plates, and 270 other illustrations. The first portion contains an historical sketch of the metals, and a summary of what is known of them in all countries of the globe. Particular attention is given to the lead and zinc producing districts of North America, with which the Missouri product is brought into competition. A chapter is also devoted to the metallurgy of the metals, and the various processes are described with sufficient minuteness for all practical purposes. Concise tables of the production in the United States are also given in this connection, together with the prices.

The second section outlines the history of mining in Missouri and the general geology of the southern half of the state. The development of mining in the state is traced during a period of nearly 200 years, from the time of the earliest explorations. The physiographical characters of the lead and zinc regions are described at length. The geological formations containing the ores under consideration are referred to in a general way, and considerable detail entered into in the case of the more important localities. The lithological differences are compared and some of the salient structural features pointed out. Under ore deposits is a full consideration of the distribution, of the form, structure and composition of the ore bodies, their manner of formation, and the origin of metalliferous veins. Concerning the latter topic, the various theories are set forth in considerable detail and their application to Missouri deposits clearly given. Smelting and manufacturing receive the attention they demand, and full statistics are given regarding the production of the two metals in Missouri, the

prices received from year to year, and the total output of the various counties.

The third part is an account of the Missouri mines, with a systematic and detailed description of the important developments and occurrences of lead and zinc. Three districts are recognized: the southeastern, the central and the southwestern. Here is incorporated all the detailed information concerning the various mining camps. Many of these are mapped in detail and the workings of typical individual mines plotted.

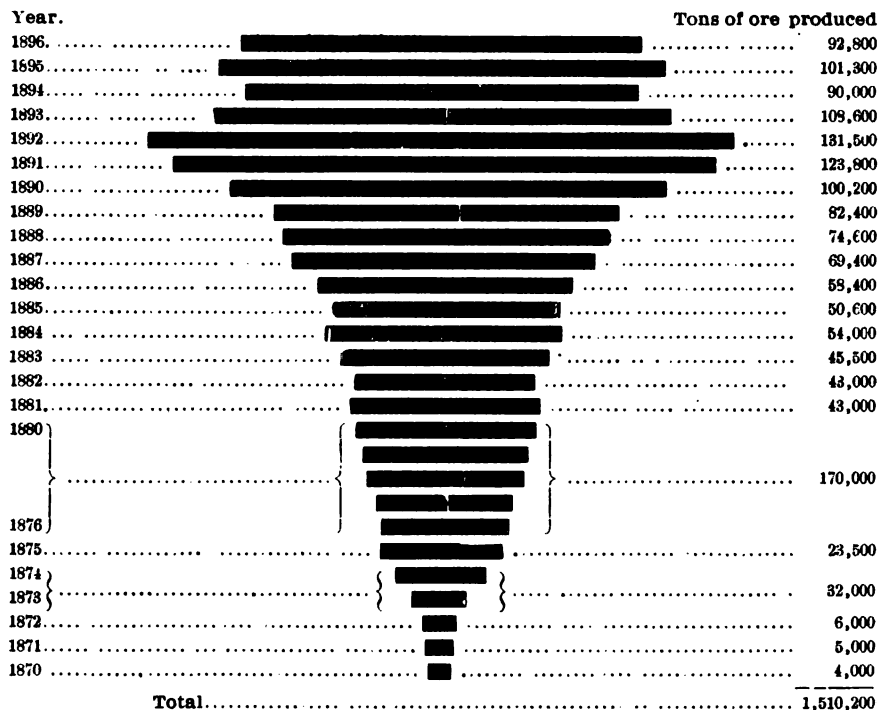
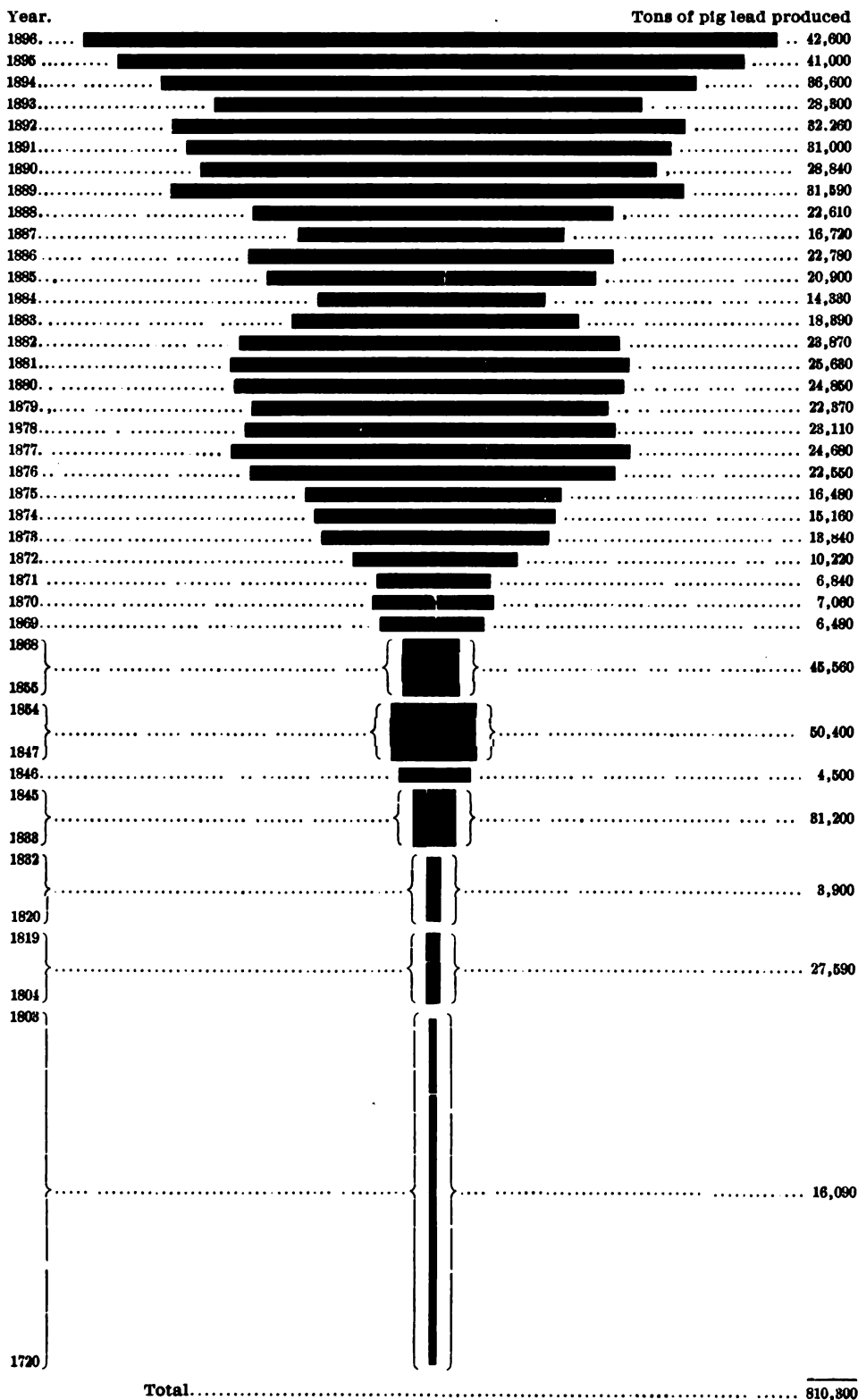


Figure 2. Growth of Zinc Production.

Detailed inspections were made in 43 counties all lying south of the Missouri river. These are given in the list below, and the commercially productive counties are shown on the annexed map (plate III).

Polk,	Phelps,	Reynolds,	Cape Girardeau,
Dade,	Maries,	Cole,	Madison,
Lawrence,	Ozark,	Morgan,	St. Francois,
Newton,	Ste. Genevieve,	Camden,	Jefferson,
McDonald,	Christian,	Hickory,	Osage,
Barry,	Taney,	Benton,	Miller,
Stone,	Douglas,	Dallas,	Laclede,
Greene,	Webster,	Oregon,	Pettis,
Washington,	Wright,	Carter,	Jasper,
Franklin,	Howell,	Ripley,	Moniteau,
Crawford,	Texas,	Bollinger,	Perry.



PIG LEAD PRODUCTION IN MISSOURI.

The rapid expansion of lead mining in the state is graphically represented by the accompanying chart (plate IV) of the productions.

While the oldest branch of mining in Missouri was for lead the youngest was for zinc. The productions of the ores of the latter dates back only 25 years. The rapid development of the zinc industry is shown by a comparison of the annual outputs (figure 2).

A STUDY OF THE CRYSTALLINE ROCKS.

As a foundation for an exhaustive treatment of the crystalline rocks suitable for building stones a detailed study both in the field and in the laboratory was undertaken. A noteworthy feature of the latter work was a very thorough examination not only in thin slices under the microscope, but in accordance with other modern petrographical methods. The different varieties from all parts of the region in which the crystallines occur were tested. One of the results has demonstrated that the granites of Missouri are the most durable of any in the country. Those mineral constituents which in most granites decompose most readily are nearly or entirely absent in the Missouri stones. For all kinds of building, constructional and ornamental work these stones are unrivalled by any in the world. Moreover, the granites and porphyries of southeastern Missouri are of unusual interest and great commercial value, for the reason that they are the only crystalline rocks occurring in the Mississippi valley between central Arkansas and lake Superior, and between the Appalachians and the Rocky mountains. The development of these areas is therefore of special importance on account of the wide extent of territory they are capable of supplying with a high grade of building and ornamental stone.

Aside from the important bearing it has on the work of the building stones of the whole state the investigation embraced a mapping of all the areas. Not only did the microscopical character receive particular consideration, but the mineralogical composition was determined in great detail. By this means comparisons were made with similar rocks from other localities which are now used largely for building materials, and with which the Missouri stone must come in competition when placed on the market. In addition to discussing the topics already mentioned there is also taken up the general geology of the crystalline rocks and the relations of the various masses to one another. Since the rocks considered in this connection are the only ones found within the limits of the state which are truly eruptive origin, the subject deserves more than a passing notice, both from a scientific and a popular standpoint. The fact that one part of the state was once the

seat of energetic volcanic action creates a widespread interest in these rocks.

The report comprises 150 pages, and 30 plates. The granite rocks are considered in the following counties :

Ste. Genevieve,	Carter,	Wayne,	Crawford,
Iron,	Washington,	Butler,	Shannon,
Reynolds,	Madison,	St. Francois,	

HYPSONETRY AND THE DETERMINATIONS OF EXACT ELEVATIONS.

An important branch of incidental work which has been recently finished is the reduction of the elevations of all railway stations to the datum of mean sea level as determined by the precise lines of level run by the Federal government. As set forth in a former statement, "the subject of hypsometry of the state has never received exact investigation.

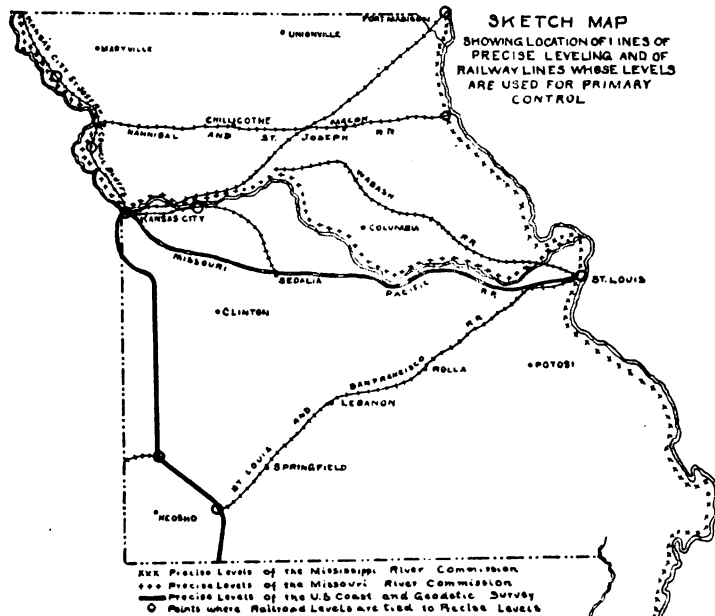


Figure 3. Lines of Precise Levels in Missouri.

The elevations of different points in the state were only approximately determined, and the distribution of the zones of equal altitudes were not defined. In connection with mapping, it becomes necessary that the relative elevations, at least, of various points in the state which are included within the different areas to be mapped, should be known with reasonable exactness. The datum to which all such elevations are referred is the mean sea level; and in all cases it is necessary to reduce all assumed altitudes to this standard. The primary base-lines are the lines of precise leveling of the Mississippi and Missouri River

commissions along the respective streams, and the trans-continental line of the U. S. Coast and Geodetic survey which traverses the state. These are shown in the subjoined cut (figure 3). The secondary base-lines are the lines of leveling for the various railways, where constructed or surveyed throughout the state, as embodied in their profiles or level books. As the methods by which railroad leveling is done are far less exact than the precise leveling of the government surveys, errors in the determinant of altitudes frequently occur, and, in order that their results may be used, the errors must be detected and eliminated. For these purposes, profiles or lists of elevations along all the various railroads were secured." These were compared at their intersections, and all the discrepancies which were detected were inquired into and corrected. As the various lines were adjusted, a net-work of lines of level throughout the state was found, upon which may be based all mapping.

The results which are now completed, give a corrected list of elevations along all the lines of railroad, and also an index arranged alphabetically. It constitutes a report of nearly 100 pages. Aside from its invaluable aid in connection with the work of the survey, it satisfies a great and ever increasing demand for information of this character.

MAPPING OF THE MINING DISTRICTS.

There are certain areas in different parts of the state, which on account of the great importance of the mineral deposits which occur, cannot be adequately and properly represented on the same scale of maps that is ample for the greater portion. Some of these are already completed and others well advanced. In the preparation of the maps and reports upon these particular localities it has been found advantageous in the case of some of the most important mining districts to take as the unit a rectangular area measuring 15 minutes of latitude and longitude. This, on a scale of 1:625000, or one mile to an inch, gives a map about 13½ by 17½ inches. The unit is called a folio, or sheet, and the reports on the areas, which are named after the principal town within its borders, sheet reports. Four of these sheet reports have been completed, viz.: the Higginsville, Bevier, Iron Mountain, and Mine la Motte. Of these two are in the coal region of the west-central and north-central parts, and the other two in the iron and lead district of the southeastern part of the state.

The first of these, the Higginsville sheet, includes part of Lafayette county and a small portion of Ray, and embraces an area of nearly 232 square miles. The report accompanying the map describes in great

detail the geological features and structure, the disposition, extent and available tonnage of the coal seams. The other mineral resources are fully described. The forestry and principal soil-producing formations are treated at length. There are about 100 pages of descriptive text.

The Bevier sheet report in a similar way is based upon a detailed examination which has been carried on in portions of Macon, Randolph and Chariton counties. This account is embraced in about 85 pages, with suitable illustrations.

The Iron Mountain sheet covers parts of Iron, St. Francois and Madison counties. It embraces the region which has long been the great iron-producing district of the state, and of the Mississippi valley. There are 95 pages in the report accompanying the map and the sheet of geological cross sections.

The Mine la Motte sheet includes the northern part of Madison and the southern part of St. Francois county, besides a small portion of Ste. Genevieve county. This includes the oldest lead-producing mines in the state, and the only silver mines yet opened in Missouri. The granites of this area are unexcelled, but are scarcely developed. There are 130 pages of description.

The four accounts together form one of the volumes of the regular series of reports. Another similar volume containing five sheet reports is practically completed, but not yet printed.

INQUIRY RELATIVE TO THE PHYSICAL FEATURES OF MISSOURI.

Another line of work which was taken up incidentally in connection with other investigations, but which nevertheless is none the less important and instructive is the inquiry regarding the origin of the physical features of the state. Missouri is the first state in the Union to accomplish a piece of work of this kind and the results obtained have amply repaid the efforts expended. The report contains 100 pages, properly illustrated by explanatory figures and plates. It has a two-fold bearing. First, it forms a basis for modern geographic study in the public schools of the state; and, second, important geological and economic questions are greatly simplified and an immense amount of labor saved by a proper interpretation of the principles set forth.

It is perhaps not generally known to the people of the state, that during the last few years there has been a complete revolution in the methods of teaching geography. The account of the Missouri features guided by the modern principles brings in a concrete case, one in which all pupils are especially interested in, within the grasp of every one, and thereby adding zest and active interest that is absolutely unattainable otherwise. It may be mentioned in this connection that in a

new school geography that is used widely in Missouri the entire part relating to the state has been based upon this work.

The bearing upon the facts obtained upon general geological work need not be explained in detail. Suffice it to say that it is one of the greatest aids to mapping correctly large areas, and to the proper interpretation of geological features. Notwithstanding the fact that this branch of investigation is the youngest of the geological sciences, it is one of the most suggestive and helpful that has ever been established.

DISCRIMINATION OF THE SURFACE DEPOSITS.

The examination of the unconsolidated material lying above bed-rock, particularly the glacial drift and the attendant deposits of the northern half of the state, had its inception in a reconnoissance of the region for the purpose of getting data regarding the soil work subsequently to be taken up, and the location of the deposits of the various earths, sands, gravels and road materials.

The essential results from the present phase of this work was the determination of the distribution and the limits of the different kinds of surface formations, or Quaternary deposits. Further than this there were also made out the general character of the several classes of formations, and their successive relations. The report comprises a full and comprehensive view of the entire subject occupying 100 pages, illustrated by 10 plates and a sketch-map showing the geographic distribution of all of the Quaternary or Pleistocene deposits. There is also included a summary of the Pleistocene history of Missouri.

EXAMINATION OF THE CLAYS.

The investigation of the properties, uses and distribution of the clays has revealed an unexpected richness and variety of deposits suitable for nearly every kind of ceramic ware. The examination has a peculiar value, and the thoroughness with which it has been conducted lends special interest. The practical experimental work on clays has never before been attempted in a broad way in any state in the Union, and nowhere in the Mississippi valley has this class of material received so careful a consideration. In the testing of the clays, not only the chemical, but also the physical properties are determined. Through the latter, especially, the various comparisons may be more thoroughly appreciated, and the exact character of the different deposits more readily understood. The following outlines the method, taking for example a sample of typical fire clay.

A preliminary examination shows:

Color varying from light to ash drab.

Texture nearly uniform, fine-grained, compact.

Taste "lean," gritty.

Slacking takes place slowly, the mass falling into irregular granules, with little uniformity of size.

Accessories: Pyrite not perceptible; sand as grains from one-tenth to one-thirtieth of an inch in size, freely disseminated.

A physical examination shows:

Specific gravity, 1.95.

Plasticity, as determined by working a clay paste, is eminent; as determined by the tensile strength of air-dried briquettes, it has a maximum of 172, the average of ten samples being 155 pounds to the square inch.

Water required to make a plastic, easily worked paste is 15.4 per cent.

Air-shrinkage, in drying bricklets ranging from four inches by one-fourth inch by one-half inch to eight inches by four inches by two inches, averages 5.6 per cent in ten samples. It can be dried rapidly in a warm air-bath at 125° to 200° F. without breaking.

Fire-shrinkage, in burning air-dried samples at a vitrifying heat averages 2.3 per cent in three samples; requires care and slow heating to avoid cracking.

Total shrinkage, or the sum of the fire and the air contractions, averages 7.9 per cent, which is remarkably low.

Fusion takes place about 2,400° F., or a white heat; incipient vitrification takes place at 2,100° F., or at a bright cherry-red heat.

Color of burned clay is light-gray.

Conclusions: This fire clay is a fairly good refractory material and can be used for temperatures as high as 2,300° F., or a very bright cherry heat. It admits of rapid air-drying without cracking, and does not fissure readily in firing. The total shrinkage being very low adds greatly to its value in any practicable application of the clay. Being highly plastic, it moulds admirably. The burned ware is strong. The clay, when washed, may be used successfully by potters. It is even possible that a white-ware may be produced if the clay is properly washed and treated.

This test of the physical properties is in nearly every case accompanied by a chemical analysis in order not only to determine the composition of the particular samples but to enable comparisons to be instituted between the Missouri varieties and those of other localities. In making the tests the object has been to sample typical deposits in the different counties. By this means a series of standard examples is established with which other and neighboring deposits may be directly compared.

The report contains over 630 pages, divided into 20 chapters and illustrated by 40 plates and several maps, besides numerous cuts. Among the subjects exhaustively discussed in this report, are:

1. The origin and composition of the clays of Missouri.
2. The methods of sampling and analysis.
3. The physical and chemical properties of the various clays.
4. The microscopical examination of clays and its value in the determination of the value of a deposit.
5. The uses to which the various kinds of clay are and may be put, and a consideration of the best varieties adapted to each specific purpose.

MISSOURI GEOLOGICAL SURVEY

CHARLES R. KEYES, State Geologist

SKETCH MAP OF

MISSOURI

SHOWING THE KINDS AND DISTRIBUTION BY COUNTIES
OF THE

Clay Deposits and Clay Industries
1897

LEGEND

POTTERS' CLAYS



SHALES



BRICK CLAYS



CHINAWARE CLAYS



DRAINTILE CLAYS



BALLAST CLAYS



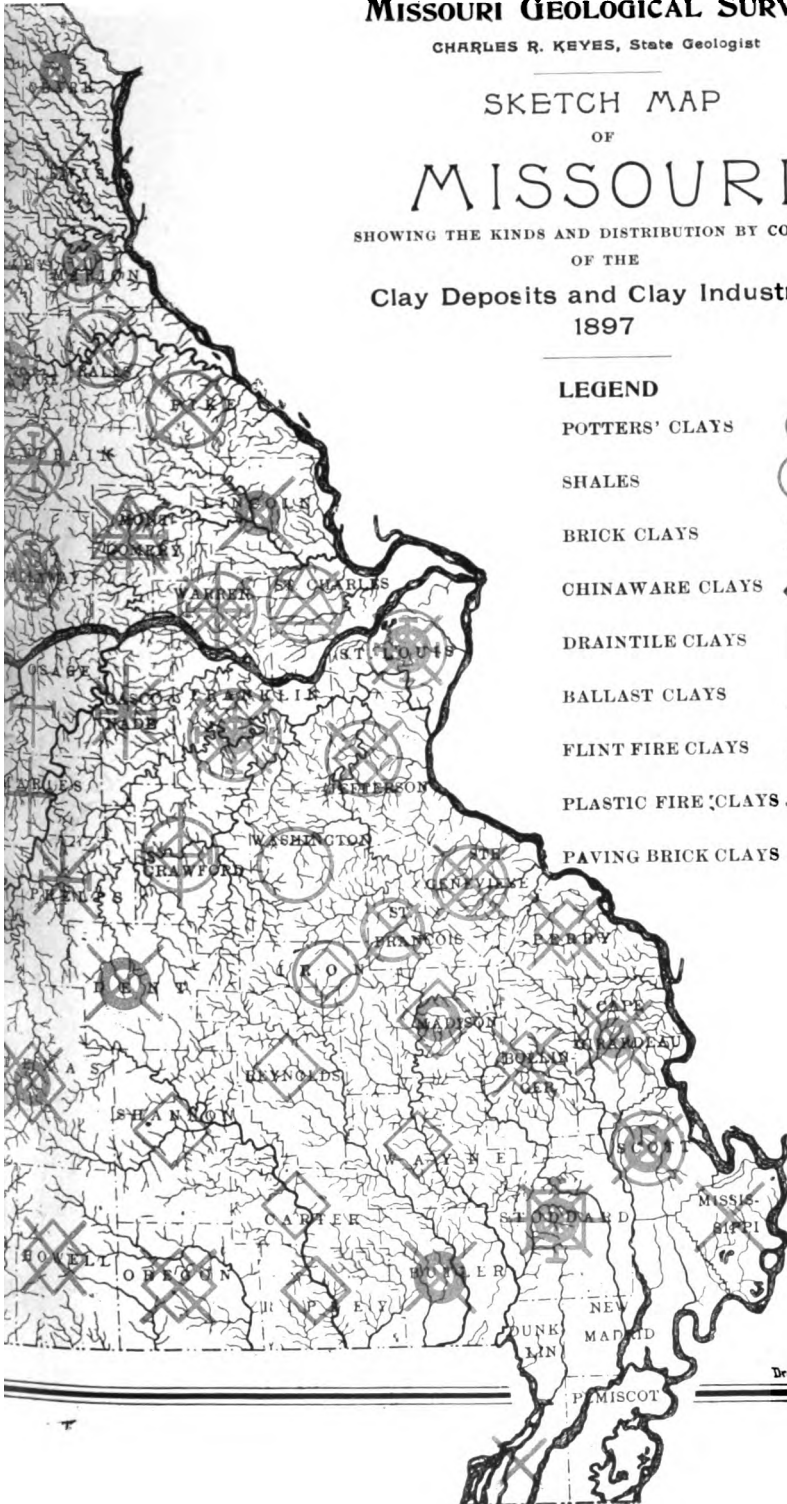
FLINT FIRE CLAYS



PLASTIC FIRE CLAYS



PAVING BRICK CLAYS



Drawn by T.B. Marshall

6. The general geology of the state with special reference to clay deposits, their distribution and availability.

7. The brick and draitile clays, the localities yielding the best qualities and the methods followed in rendering the poorer grades workable. There is also embraced a special consideration of the clays used in making paving-brick and sewer pipe. The recent extensive use of brick as a paving material, and its superiority over many substances, has rendered the subject of brick for this purpose one of very great importance, and one to which sufficient attention has not yet been paid. Paving streets with hard bricks is fast becoming popular in the larger towns and cities. Tests are continually being made which go to prove that the durability of a street paved with good vitrified brick compares more than favorably with that of streets paved with other material.

8. Fire-clays and other deposits for the manufacture of refractory products. There is given in this connection extensive comparisons of the raw materials from the different localities in the state, and reference to noted places beyond its limits. Deposits of this material have been found in large quantities and of very superior quality.

9. Pottery clays, their properties, distribution and location; also the materials used for glazing and in mixtures.

10. Ohina clays and kaolin, of which large quantities have been recently brought to light, especially in the southeastern part of the state.

11. The principal industries based upon clays, and descriptions of the works and clay-pits.

12. Preparation of clay for manufacture into the different products, and the methods used.

13. Recommendations for better methods of manipulation. The importance of raising the standard of excellence of clay goods cannot be overestimated. It not only aids directly the manufacture of the products, but indirectly greatly benefits every citizen by providing him with a superior quality of material at no higher a price than he would otherwise give for the inferior article.

14. Complete statistics in regard to the production of the various kinds of clay wares.

Altogether, the report on clays forms one of the most valuable contributions to economic geology ever published, not only in Missouri, but in the entire United States. It completes one of the most important lines of work yet undertaken by the survey. The distribution of the different kinds of clay in the various counties is represented on the accompanying sketch-map (plate v).

THE WORK IN PROGRESS.

As fully explained in a former report the investigations concerning the natural resources of the state are carried on along parallel lines. While apparently covering much the same ground they do not necessarily occasion duplication in either field work or publication. The very nature of the existing conditions which makes it impossible to take up all lines of inquiry in the beginning renders it necessary to give greater prominence to some branches of work and to finish them up before expanding actively in new directions. As the work is completed in the various fields and the reports are made, the efforts of the survey are directed to other branches, only incidental notes being continued on those subjects which have been reported upon. Attention has already been called to some of the work which may be regarded as completed.

Of the various lines of investigation which are more or less well advanced or which are nearing completion special mention should be made. At the same time that these lines are carried out, much information, as may have been already inferred, is constantly accumulating on related subjects, so that when these are taken up to be pushed vigorously to completion a large number of facts and notes will have already been acquired.

SPECIAL LOCAL OR AREAL GEOLOGY.

In the consideration of certain work which had been completed, mention was made to the detailed mapping of mining districts of more than ordinary importance. Attention was called particularly to four such districts, or sheets, which had been finished, and the reports on which constituted a volume of the regular series of the Survey publications. There are certain other areas of similar character the work on which has been finished, the maps made, and the reports written. The printing of these will be done in the near future. These districts are:

5. The Clinton sheet, in Henry county.
6. The Calhoun sheet, occupying portions of Henry and Benton counties.
7. The Lexington sheet, which is largely in Lafayette county, but partly in Ray county.
8. The Richmond sheet, including parts of Ray and Carroll counties.
9. The Huntsville sheet, embracing portions of Randolph, Charlton and Howard counties.

The detailed topographic mapping of several other areas is also finished and the reports of all can probably be prepared during the ensuing biennial period. These are:

10. The Aurora sheet, occupying parts of Barry, Lawrence, Charlton and Stone counties.
11. The Joplin sheet, composing the western portions of Jasper and Newton counties.
12. The Carthage sheet, including eastern part of Jasper and Newton counties.
13. The Bollivar sheet, in Polk county.
14. The Warrensburg sheet, in Johnson and Lafayette counties.
15. The Bonne Terre sheet, covering parts of Washington and St. Francois counties.

This detailed topographic and geological mapping has been accomplished for nearly 3500 square miles, and is distributed in 23 counties as follows:

NORTH CENTRAL MISSOURI:

Macon,
Randolph,
Charlton,
Howard,

SOUTHWESTERN:

Polk,
Jasper,
Newton,
Lawrence,
Barry,
Stone,
Christian.

WEST-CENTRAL AND NORTHWESTERN:

Ray,
Carroll,
Lafayette,
Johdson,
Henry,
Benton,

SOUTHEASTERN:

Washington,
Ste. Genevieve,
St. Francois,
Iron,
Reynolds,
Madison.

THE COAL AND ASSOCIATED DEPOSITS.

The plan of operation as outlined in the previous biennial report has been continued. Good progress has been made. At the present rate of advancement it is believed that a report can be made ready for publication during the ensuing year. The investigation of the coal deposits of the state was one of the first subjects taken up after the organization of the survey, but owing to conditions which could not be anticipated it was necessary to almost suspend work for awhile in order to complete other lines which were farther advanced towards completion. Notwithstanding the fact that this material ranked among the most important of the mineral resources of Missouri, and the state stood ninth among the states of the Union in coal production, less was known concerning its structure and distribution than perhaps any other deposit of economic value.

The investigation was begun by selecting the localities in which mining was in progress, it being the object to obtain all data possible from districts already well known. "As an outcome of this preliminary work there has been printed, and in large part distributed, a preliminary report upon the coal deposits of the state. This report con-

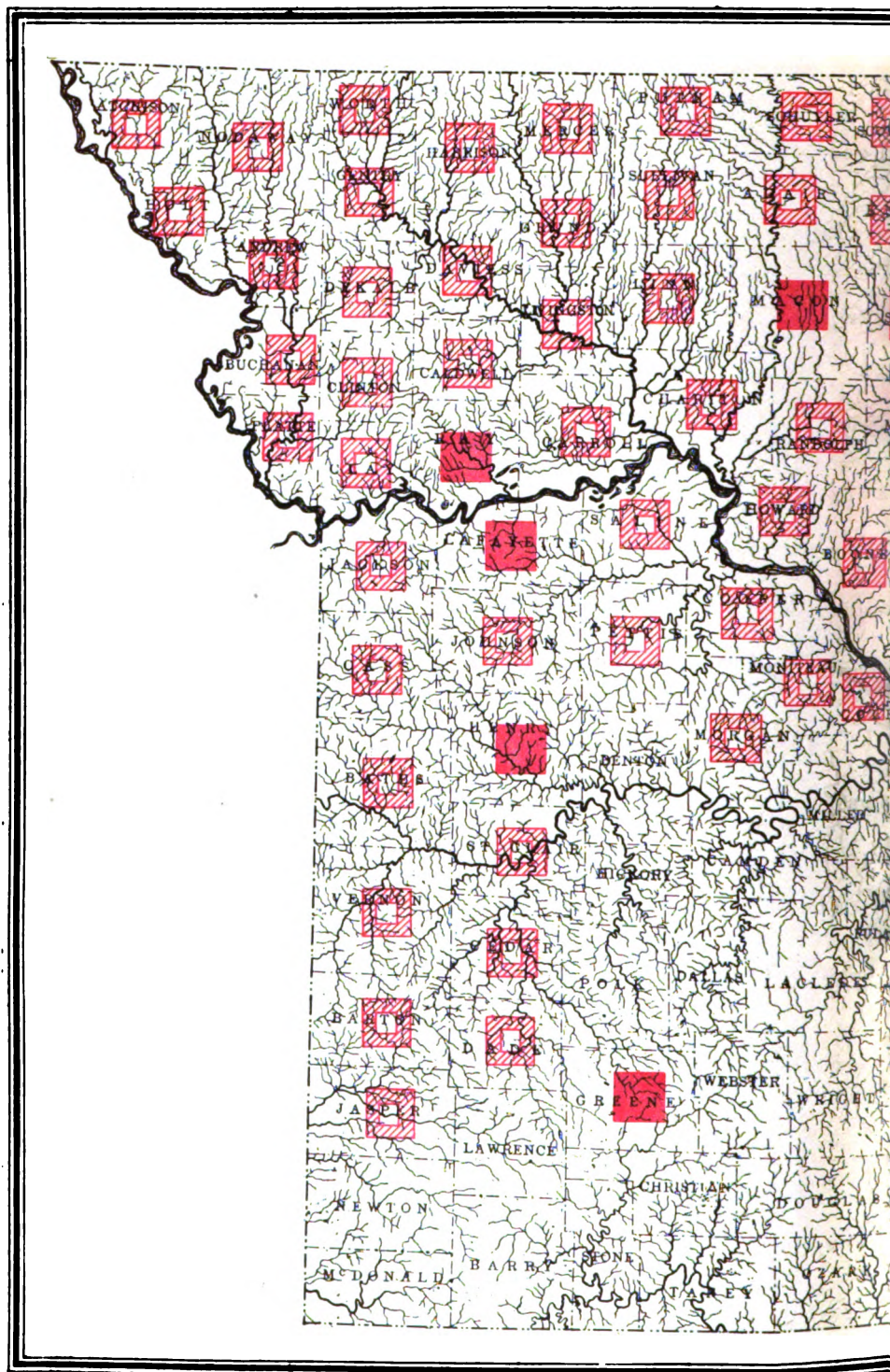
tains over 200 octavo pages. As is implied by its title, however, and as is distinctly expressed in the preface, it is essentially a preliminary report. It is in large part a presentation of only the bare facts of the occurrences of the coal, the facts of most direct economic importance, and these are presented in a popular way. The justification for the presentation of such preliminary report lies in the urgent demand for information concerning the subject; but, though this report is calculated to satisfy this demand to a great extent, it should by no means be taken as a measure of all that can be presented, and all that will be attained through the work in the coal regions."

The most important part of the investigation yet remained to be completed. Practically nothing concerning the correlation and stratigraphy of the seams has heretofore been published that applies to the state. Since the appearance of the preliminary report, much valuable information has accumulated, but during the past biennial period the subject has been pushed with renewed vigor. At the outset it was found that in order to make satisfactory progress it was necessary to carry on the work in a perfectly systematic manner. Localities must be studied first which are likely to furnish most readily a key to the structure, character and disposition of the coal beds over large areas. The leading geological features of these districts must be carefully made out, and the examination extended into neighboring regions. In this way the extent of territory covered and the amount of practical information secured is far greater than can possibly be obtained in any other way.

The area of the coal measures of Missouri includes nearly 23,000 square miles; besides, there are numerous Carboniferous outliers, or isolated areas, along and beyond the borders of the productive measures, which make up many additional square miles. The investigation of the coal deposits of the state is thus seen to be a work of no small magnitude. Detailed attention to the coal industry in all its phases involves much labor which cannot be completed as soon as might be desired; it requires time to make satisfactory observations, to accumulate all facts, and to carry on proper tests.

In the final report on coal are included :

1. A general sketch of the coal deposits and the geology of the region.
2. An outline of the principles involved in the correlation of strata.
3. A detailed account of the geological features of the coal district, embracing a full description of the different kinds of beds and their associations, the minute structure of the coal-bearing strata, the exact relations of the different seams, the distance from the surface



MISSOURI GEOLOGICAL SURVEY

CHARLES R. KEYES, State Geologist

SKETCH MAP

OF

MISSOURI

SHOWING THE PROGRESS MADE IN THE EXAMINATION

OF THE

COAL DEPOSITS

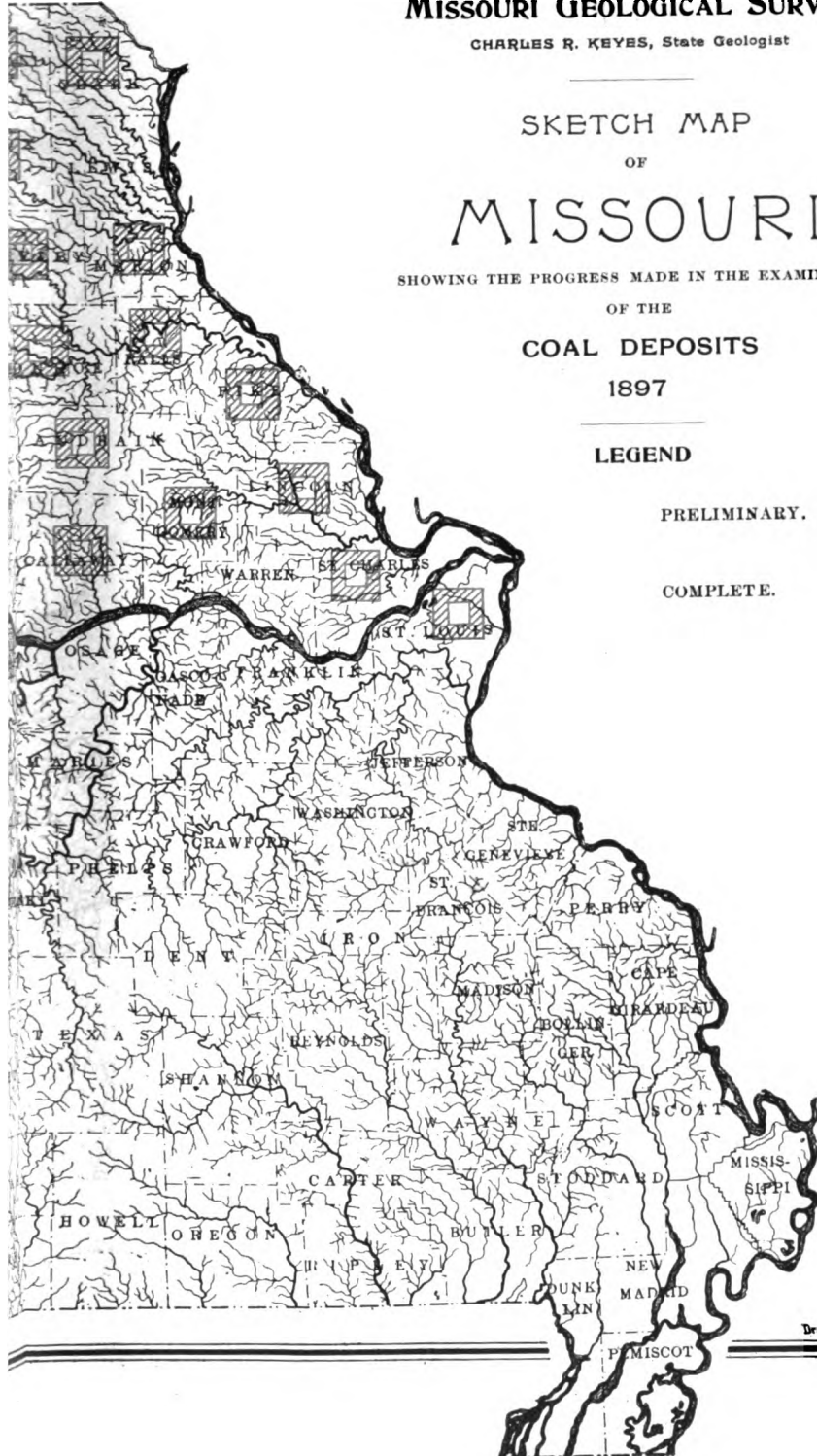
1897

LEGEND

PRELIMINARY.



COMPLETE.



Drawn by T. B. Mearns

that it is necessary to go in order to reach them, the pointing out of notable and easily recognizable strata which may serve as guides in searching for particular veins, and all kindred information of practical import.

4. A description of the uses and properties of the Missouri coals, with tables of chemical analyses of all the principal varieties from the different counties, the adaptabilities of the various kinds for steam, domestic and metallurgical purposes, and for gas-making. In this connection will be considered all information tending towards greater development of the coal industry, including the utilization of coal-dust, slack and such lignites as may occur.

5. A discussion of practical mining in the state, the methods employed and improvements which may be made, the kinds of machinery used and its advantages, the best plans and the most suitable machinery for prospecting.

6. A description of the coal plants and the other vegetable remains which are associated. This embraces all the plants which go to form the coals.

7. An account of the animal organisms, the remains of which are entombed in the various beds associated with the coal seams, and which are of such great practical aids in the determination of the horizons.

The counties in which preliminary inspections have been carried on are indicated on the accompanying sketch map (plate VI); and also those in which the examination may be considered as completed. The great importance of the industry and the growth of coal mining may be graphically shown by the annexed diagram (plate VII).

THE BUILDING AND ORNAMENTAL STONES.

The progress made in the investigation of the building stones has been satisfactory and the results obtained have been important. The general scheme of operation is essentially the same as outlined in another place. A few changes in plan were made as the work advanced, but they were more of the nature of readjustments to meet new conditions which arose. Mention has already been made in detail of the microscopical examinations undertaken in regard to the crystallines, the granites and the porphyries, and of the detailed mapping, in St. Francois and Madison counties, of the granites that are suitable and available for building and all constructional work; and those which are not so well adapted for the purposes named.

The work has gone on far enough to demonstrate, as was recently fully described, that in variety and quantity of good stone suitable for building and all constructive purposes, no state in the Mississippi val-

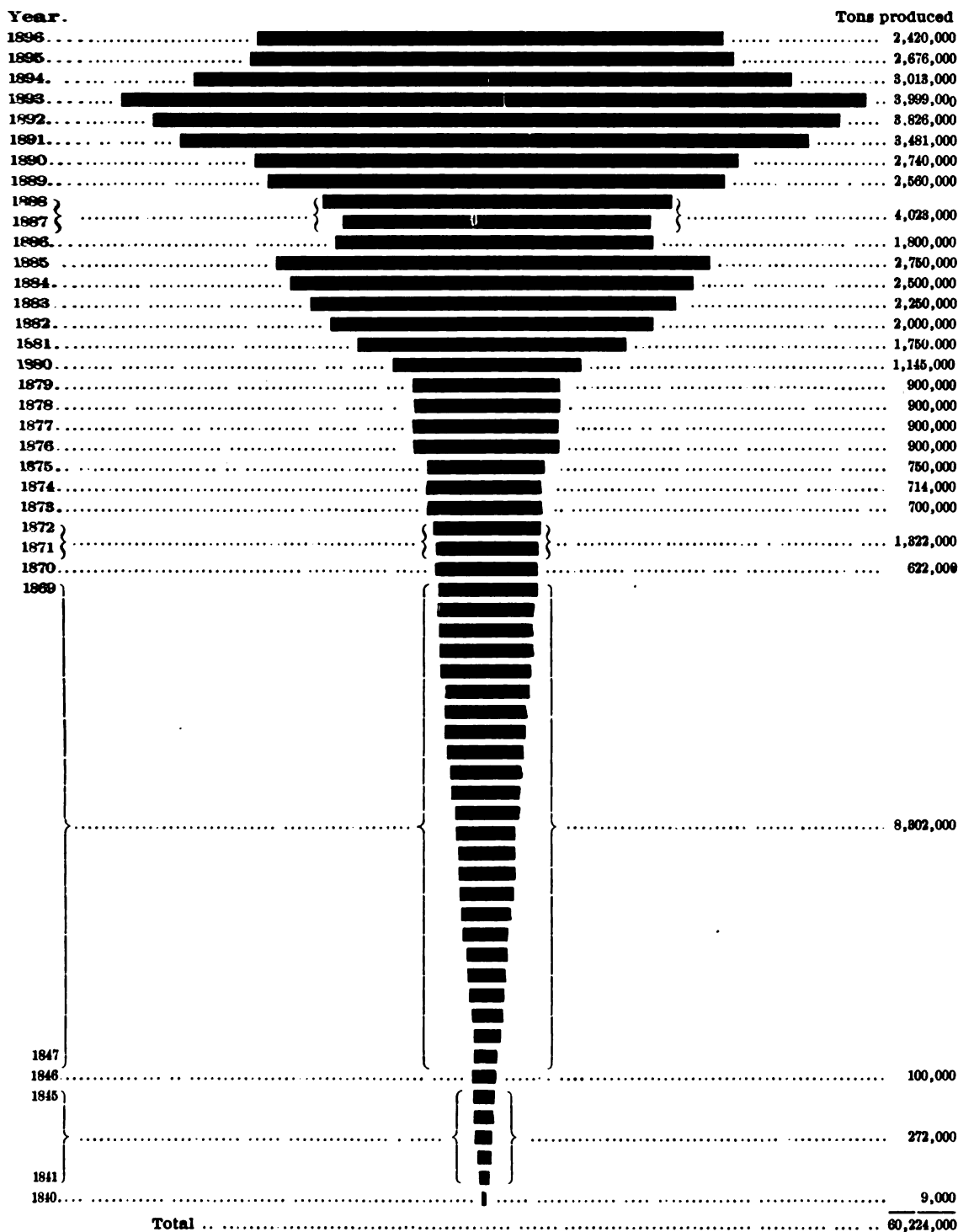
ley is surpassed by Missouri. Heretofore no systematic investigation of the building materials of the state has ever been accomplished. That Missouri has excellent grades of quarry stones is manifest from the demands made for certain qualities. That the state should have many other good building stones is not unreasonable to expect. Nevertheless it is a matter of material regret and constant solicitude that the state continues to go beyond its boundaries for many of the better grades of stone for building. Of the vast sum of money which is expended every year for stone used in constructions of all kinds, a large proportion goes to other states. Hence, it is greatly to be deplored that a more exact knowledge of the state's building stones was not acquired years ago. Recognizing this deficiency, an investigation of the building materials of the state was begun with the first organization of the geological survey. The subject soon proved to be so much larger than was anticipated that it had to be divided, different portions being taken up by different persons. Some of the topics have already been reported upon, while others have received as yet, but little systematic attention.

The importance of the inquiry can hardly be overestimated. It is a fitting subject to be taken up by the state, and benefits all citizens alike. Architects and engineers commonly have neither the apparatus nor the inclination to make extensive tests in regard to local building materials. Consequently, stone is used which already has its reputation established. Thus, the lack of authoritative information in regard to local resources causes the rocks of the state to be discarded, and building stones to be transported half way across the continent, and often placed upon ledges of rock in every way their equal, or even their superior. The quarrying industry at home does not receive the support it should, while foreign markets are entered and purchases made.

As is well known to the quarrymen, the chief factors which determine the value of building stone are accessibility, durability, strength, structure and reputation. No matter how excellent a stone may be, it is valueless for constructional purposes if it does not have good transportation facilities. Durability is a phase of the subject which cannot be determined readily from hand specimens, and is usually brought out through experience, though the microscopical examination in thin slices is an unerring means of accomplishing the same end, and the value of these examinations in the case of the massive crystallines is perhaps the greatest of any one test. Stones, which ordinarily withstand the influences of atmospheric agencies, readily waste away when exposed to conditions different from those of their native places,

MISSOURI GEOLOGICAL SURVEY.

PLATE VII.



GROWTH OF COAL IN MISSOURI.

and the acid-laden air of great cities is especially deleterious to rock. The resistance to weathering is ascertained best in the field by careful examination of the native ledges. These observations may be supplemented by tests in the laboratory. Strength, however, is usually the only factor tested in determining whether or not a given stone shall be used.

An outline of the full scope of the investigation may be briefly noticed. In making the observations, special attention is given to the distribution of the ledges best adapted to building purposes, the properties recommending the various kinds of stone and the effects of weathering upon the natural outcrops. Special attention is given to the minute structure of building stones and changes which they undergo in the process of weathering, as revealed by the microscope. This is practically a new field as regards constructional materials, and has never been systematically applied to rocks as building stones. It promises very fruitful and interesting results.

In the report which has already been begun it is intended to give full descriptions of the localities and of the quarries now opened, statistics as to production and the methods of getting out the stone. Illustrations of some of the finer grades of the ornamental varieties and the more important buildings and constructions erected from Missouri stone will also be given.

THE FORMATIONS AND STRUCTURE OF THE OZARK REGION.

There is a large part of southern Missouri which has been affected to a marked degree by mountain-making forces, not once, but repeatedly. The present Ozark uplift is of comparatively recent date, and many features are presented which are not found in other parts of the state. The structures existing are totally different from those found elsewhere in Missouri. They have had a marked effect upon the deposition and distribution of the ores which occur. Until very recently the geological formations themselves were little understood; their age and their relations to one another were either entirely unknown or else surmised in the most general way; their vertical limits and lateral extent were only vaguely made out; the geological horizons of the various ore deposits was often beyond even a rough guess. In fact, the Ozark region has long been regarded by geologists as veritable *terra incognita*. All around it the formations had long been determined. As a key to the law governing the occurrence of the ore deposits the geology of this region urgently demanded deciphering. Great advancement has been made in this respect, and the phenomena which have long been a puzzle to the workers in the region

are being rapidly eliminated. No more important inquiry that is strictly geological has yet been undertaken in the state, and none promises to be more fruitful of lasting results that are not only scientifically interesting but economically valuable.

SUMMARY OF THE GENERAL GEOLOGY OF THE STATE.

The materials for the description and discussion of the geological and structural features of the Missouri formations have never been brought together so that the subject could be adequately treated in a broad way and in accordance with modern methods. The collection of these materials is necessarily slow at best, and the work can only be undertaken incidentally along with the investigations in the various branches of strictly practical bearing. Much of this information can be obtained as the work along the more directly useful lines is being prosecuted and without interfering with them.

It is a well known fact that in its accomplishment all geological investigation demands the settling of certain broad fundamental questions relating to the origin and succession of the geological formations; and that these must be considered in order that the best results may be secured in regard to the more strictly economic work. Some of these problems are far reaching in their bearing. They are not confined to a single district, nor to a single county, but often extend over a greater part of the state, or through several states. Fortunately, as contributing to the rapid completion of many of the branches taken up, not a few of these problems had already been partially or wholly solved before the work of the present survey had begun. A general study of the rocks, of their arrangement and of their relations in this and adjoining states, had been made. These results greatly facilitated the preliminary investigations which invariably must precede all detailed examinations. With the broad general questions of interstate importance already tolerably well understood, those which have to do more particularly with the state alone are much more easily taken up and more readily solved than they could be otherwise. There is considerable work of this kind yet to be done. A discussion of it embraces a somewhat generalized and co-ordinated consideration of the lithological characters of the different formations, the structure and arrangement of the various beds and a classification of the formations in accordance with the latest criteria of geological science. The direct bearing of the general geological problems upon the more strictly economic phases of the several topics is shown more in detail in connection with the remarks on the different subjects of which special mention has been made.

Sufficient facts have now been brought together to enable the general scheme of the final consideration to be fully outlined. It includes a general description of the geological features and structure of the upper Mississippi valley, particularly as applying to Missouri. It takes up the separate geological formations and describes in detail the characters and distinguishing features of each. It considers the arrangement, succession and thickness of the formations, the variability of the different strata, the unconformities and deformations. It notes particularly the useful minerals and substances occurring in the different parts of each formation, and points out how most readily to detect the deposits, it considers also other usefully materials which are not as yet utilized. It discusses the origin, conditions of deposition, and the associations of the various beds.

Some of the more significant problems that were solved in this connection since the last report were: The determination of the exact relations between the so-called lower and upper coal measures across the state; the practical subdivision of the principle coal-bearing series into three stages; the settlement of the exact basal horizon of the Carboniferous; the recognition of the upper part of the lower Carboniferous or that part above the Augusta or chief ore-bearing formations in southwest Missouri; and the conclusion that the granites and other igneous rocks of the southeast are not Archæan in age, as generally considered, but younger.

THE MINERALS NOT MINED.

While no special effort has yet been made to push investigations along the various lines relating to those mineral substances which are not as yet mined on a commercial scale, facts and material for study have been constantly accumulating. Arrangements have already been made whereby the systematic consideration of these data can be carried on with the special object of ultimately bringing all the information together in the form of a mineralogy of the state. The plan of the final work is essentially as previously outlined.

The various investigations undertaken have demonstrated that there exists in the state, in addition to the ores at present mined a large number of other minerals which are not yet taken out in quantities to be of much value in trade. Some of these minerals are known to have a very considerable economic value and will necessarily soon be the subject of special inquiry. Others will be found to have only a scientific interest. Many having little or no value from an economic standpoint are now attracting popular attention and are causing considerable expenditures of money, time and labor every year, with abso-

lutely no possibility of any adequate returns. On the other hand, a number of those having great economic value are not being worked to the extent that they deserve or they have received no notice whatever. Even though many of the minerals in the state should prove to be of no commercial importance negative results are by no means without value. Proof that certain deposits are not extensive enough, or are not of a sufficiently high grade for profitable working, will be the means of preventing annually a great waste of money and energy.

In the consideration of the substances which are to constitute the foundation of the study of the mineralogy of the state there will be given a complete list of the various kinds, full descriptions of their different occurrences, a catalogue of the known localities of each and the possibilities of their extent and utilization. A careful crystallographic examination will also be undertaken. Since Missouri affords some of the finest samples in the world for this line of inquiry, the subject will prove to be of exceptional interest and value. It may be mentioned in this connection that already nearly 100 different varieties of minerals have been noted from the state.

THE MINERAL RESOURCES OF COUNTIES.

It was stated on another occasion that in conducting the areal investigation and mapping of the state a different unit from that of the "sheet" would probably have to be taken in many cases. With a large part of the state the county must be taken as the most convenient unit upon which to report. As the state is the political unit of the nation so the county is the political unit of the state. When therefore in either the larger or the smaller of the two provinces it is desirable to consider any subject with special reference to its areal distribution, the units mentioned become the natural divisions into which a complex topic may be separated. In former years this was universally the practice; in the earlier work the recorded results of investigations were contained in the county reports. At that time the country was new, and little more was required than to indicate the existence of the various deposits; moreover, the chief energies were necessarily directed toward tracing the limits of the different geological formations.

Although it has become of recent years the practice to adopt a smaller and more scientific unit as the basis of areal reports, there nevertheless remain good grounds for retaining the county as the unit in all cases except the most important mining districts. Indeed, the reason for making the county the areal unit in the treatment of the natural resources of a region are many:

1. It is the most widely known and familiar political division of local importance.

2. It is the district concerning which nearly every person in the state who is interested in natural products inquires.

3. It forms a convenient district for working out geological details.

4. It is an area the size of which is perhaps best suited to the purposes of instruction in the schools.

5. It is especially adapted to the encouragement of detailed work by local observers.

6. It is the district most commonly inquired about by investigators living in other parts of the state or in different places beyond its limits.

7. In Missouri it is an area well suited to the preparation of maps, of nearly the same size.

8. It in no way interferes with the adoption of other units of uniform size for a state atlas as occasion demands.

The investigation into the natural resources of the state must necessarily be preceded by a general reconnoissance, and in connection with this the more general examinations which are embraced under the comprehensive title of subject-work must be pushed somewhat more vigorously than the areal work. This having now been accomplished in great measure, the energies of the survey are directed more toward pressing to rapid completion the more strictly local inquiries and the work which is of more direct benefit to the people at large. It was not possible to accomplish this until certain preliminary work had been taken up. Detailed investigation of a number of counties has already been undertaken where the conditions are especially favorable. Although every county in the state must be thoroughly studied before the completion of the survey, it is readily understood that all of these districts cannot be taken up at once. Some must of necessity be studied before others. In making a beginning in this direction, the work has been governed to a great extent by the investigation as a whole, those regions being taken up first which best furnish an index to the surrounding counties, thus enabling the work to be done over large areas, and in a much shorter time than would otherwise be possible. Another important factor in determining the priority of certain counties in which operations have been begun has been the presence of volunteer and local assistants. In this way some counties containing educational institutions have afforded special facilities. The instructors of geological classes in the several colleges have given.

to a greater or less extent, attention to the natural features of the surrounding country, and have often accumulated considerable information. By utilizing the facts previously obtained, and extending the observations so as to accord with the general plan of the survey the state comes into possession of material of great practical value at a small cost. The reports of these counties will thus serve not only for purposes of class instruction, but will reach the public much sooner than they would under less favorable circumstances. In this way work has been undertaken in a number of counties, and considerable progress has been made.

In two counties work of this character is already well advanced. In Green county the mapping has been completed and the accompanying report written for final revision previous to sending to the press. In Pike county the mapping of the formations has been practically finished and good progress made in getting together the notes for the preparation of the report. The general scheme followed includes a brief general account of the surface relief and drainage, a description of the lithological characters of the different rocks and the geological structure of the strata. The principal geological subdivisions are considered separately, and the means of recognizing each pointed out. All the mineral deposits of a useful nature are described, the various localities taken up in detail, the extent and distribution defined, and the present and future values noted. The soils and minerals are also discussed, and the discriminations to be made are pointed out. Chemical analyses and practical tests of the various substances are also given. Illustrations are incorporated whenever required, accompanied also by a map on a suitable scale.

As a part of this work there will be a final summary by counties of the mineral resources of the state considered strictly from an economic standpoint, the whole forming a volume similar to the others of the regular series of publications.

INQUIRIES PROSPECTIVE.

Among the lines of work which have not yet been taken up and which have remained practically untouched there are a number of great importance. It is not necessary at this time to call particular attention to all of those lines of work which must be taken up before the survey of the natural resources of the state may be regarded as measurably complete. There are several branches which are urgently requiring early notice and these may be considered briefly.

THE ANALYSIS OF THE SOILS.

The general mapping of the different geological formations of the state has now gone far enough to enable other lines of work to go on which must find a basis in this work. The systematic investigation of the soils is one of these and the time has arrived when the consideration of this theme can be taken up with great advantage.

As the general investigation of soils has made such rapid progress during the last decade or two, it may be well to sketch briefly the course which this advancement has taken and to note what results are to be expected from such an examination. Of all the states in the Mississippi basin, Missouri is to be particularly benefited by a systematic inquiry into the exact character of the soils. Lying only partly within the drift area, fully one-half of the state's territory possesses soils which are directly dependent for their degree of fertility upon the underlying rocks. With this intimate relation between the various strata and the soils into which they graduate, the question assumes an importance that is practically impossible to arrive at in the more northern districts.

There has probably been, in recent years, no phase of geology which has attracted more attention than the study of soils. Owing to the great fertility of the virgin prairies of Missouri, artificial fertilizers have not as yet come into general use as in the older states of the Union and in the densely populated countries of Europe. Nevertheless, it has begun to dawn upon many communities, as it must necessarily sooner or later everywhere, that the soils may not yield so abundantly as years go by. In different parts of the country, the real conditions are rapidly being comprehended and efforts are being made to rejuvenate the failing soils. The awakening is even now occurring in many localities, particularly in the eastern and southern states. The subject, however, is not receiving attention only in those districts in which the soils are partly or wholly "worn out". It is beginning to be found out that in many places, even where the soil is surpassingly fertile, proper treatment may greatly increase the yield of the products raised.

In addition to the inherent qualities of the soils, there are certain climatic conditions which need careful noting. More than once during the past two decades there have been violent fluctuations in the total yields of the various crops, and at least two or three times within the period the crops have narrowly escaped almost total failure, owing to prolonged droughts. Human efforts are of little

avail in attempting to change these varying climatic conditions to counteract the elements of nature, but by directing our efforts in other directions it is possible to accomplish the same results by manipulating the soil so that it will retain sufficient moisture to carry all vegetation safely through the most protracted dry spells. The accomplishment of this is made possible through the proper chemical and physical investigation of the different soils.

In the past geology has been almost universally regarded as the sole aid to mining; but of recent years it has come to be considered that it is destined soon to be the chief factor in the advancement of agriculture. The steps toward the collection of data have already been important and many. The interdependence of the science of geology and the science of agriculture is daily becoming more and more intimate. The relations between the primitive rock ledges and the soils resulting from their disintegration are ever becoming better understood. The principle lying at the base of the more recent soil investigation is that each geological formation gives rise to a more or less well-marked type which is especially adapted to particular crops. The latest work in regard to this subject has been on the physical rather than on the chemical side, and the results have been so eminently satisfactory that it seems desirable to summarize briefly the conclusions deduced from the application of a mechanical analysis of the soils.

Regarding this phase of the subject geologist Bain, who has given the subject much attention in this part of the country, says:

"In the first place, starting with the fact that the farmer, simply from the character and appearance of the soil, is better able than the chemist with his most refined methods of analysis, to tell what kind of grain it will produce, there is reason to believe that the differences in the value of the soils are due rather to their texture and the arrangement of grains than to their chemical composition; that all soils contain sufficient food material to support crops for years; and that their value is measured not by chemical composition, but by their relations to the moisture contained.

"Moisture in a soil, or the circulation of water in it, is very important, and is believed to be one of the leading determining factors in the local distribution of plants. The circulation of water in the soil is brought about by two forces, gravity and surface tension. The first is constant, and acts always in the one direction, so that it may be practically neglected. The second acts in all directions, either by pulling the water up to the plant or away from it according to circumstances. Careful investigation and calculation has shown that, upon

an average, fifty per cent of the volume of the soil contains no solids, but is made up of only water and air, and may be regarded as empty space. If a soil is slightly moist, the water forms films around the component grains. If there is an increase of water these films thicken, and the amount of surface exposed being smaller in proportion to the weight of water, the surface tension becomes low. If, however, the amount of water decreases the surface tension increases, as the surface exposed is much greater in proportion to the less weight of water.

"In a cubic foot of soil the total surface exposure of particles is usually in the neighborhood of 50,000 square feet, or a little more than an acre. In some kinds of soil it is over two acres. This amount of space may be divided in different ways, and the manner in which it is broken up controls largely the surface tension of the soil moisture. In turn, this determines the relation of the soil to the amount of water it will hold. Experiments have shown that different chemicals have two distinct effects upon the soils. One is to directly modify the surface tension of the soil moisture; and the other is to indirectly accomplish the same result by inducing changes in the texture. Since upon the surface tension existing in the soil depends its ability to absorb and to retain moisture, important changes in the capacities of land may be brought about through the application of proper chemicals, and the power of a given soil to resist drought may be very greatly increased".

The importance of this new soil work has awakened a special interest in it all over the country, and especially in the eastern states. The Department of Agriculture, at Washington, has also taken the subject in hand, and has established a special bureau whose energies are to be devoted in this direction. The work in a general way is to be extended over the whole of the national domain. In order, however, that such an investigation of the soils may be made more directly responsive to the needs of Missouri, and the results made available at the earliest possible moment, special work in this direction must be begun by the state at an early day.

EXAMINATION OF ROAD MATERIALS.

The betterment of the highways is a subject which has recently excited wide-spread interest. The subject is largely an engineering one, and while a discussion of the advantages and general durability of good roads in the state also comes within the province of other fields, there are, nevertheless, certain phases of the question which properly come within the range of the investigations for which the sur-

vey was organized. Among the things which may be regarded as demanding attention are the localities and character of superior stones for improving the roads, the facilities for transportation and the approximate cost of quarrying and preparation. In addition should be considered the qualities and properties of these rocks. The location of good gravels, their areal extent and their quality should also receive attention. The subject of the utilization of burnt clays as a road material should be fully discussed. Some of the railroads are already using burnt clay for ballast in preference to rock, sand or gravel, with good results, so that the extension of the use of this material to highways is in reality beyond the experimental stage. During the progress of the examination of the clays certain deposits were made known in various parts of the state which were not only suitable for burning into burnt ballast for railroads but which were excellent for improving highways as well. In the Olay report Professor Wheeler says on this point:

"For macadamizing purposes in cities it is not as durable as a good tough rock as it crushes and wears too rapidly if the traffic is heavy; but for the county roads where the teams are few and the loads moderate, it would prove durable. It should be used on the very numerous county roads in the northern part of the state that become almost impassible during the spring, as it can be made so cheaply as to be within the means of any prosperous community. It can be made along the roadside where it is wanted, by the hand process, which involves no outlay for plant and only a moderate degree of skill, or the part of one head-burner; in fact it does not need the experience or care required in making charcoal, which latter process it very much resembles. Where the roads are the heaviest, it is frequently due to the presence of the very clay that makes the best ballast, and the material that would answer for this purpose probably occurs in abundance in every county north of the Missouri river. The road should be graded and crowned before surfacing it with burnt ballast, which should be put on to the depth of at least six inches, and deeper if the traffic is heavy. Such a road would be entirely free from mud in the wet weather, would give a smooth, hard surface, and is easily repaired as it wears out by the addition of fresh material. The cost of macadamizing with burnt gumbo varies according to the convenience of coal slack or other cheap fuel."

In this connection, special attention should be paid to the great dump-heaps which are always found at the mouths of coal mines over a considerable area of the state, and which, through spontaneous combustion, afford large quantities of thoroughly burnt clay. The extent

to which the products from these dumps might be used for road construction, at practically the cost of hauling the material away, is a matter of no small consequence.

THE INVESTIGATION OF WATER SUPPLIES.

The question of water supplies resolves itself into three phases : (1) the surface waters and water powers, (2) the artesian waters, and (3) the storage and well waters.

1. The surface waters include all those carried off by the streams. The supplies that they furnish is not so important as the potential condition they afford for providing mechanical power. The water-powers of Missouri appear destined to soon assume an importance previously not thought of. Since the recent great development of and the constant widening of the uses of electricity has taken place there is an urgent call for an inquiry into the utilization of the vast energies now going to waste in the rapid streams of the state, especially those in the southern half. The day cannot be far distant when the powers of the water-ways must be converted into a form of energy of the highest practical utility, capable of being transferred great distances with small loss, and of furnishing not only the light, but heat, and the means of running machinery of all kinds. The amount of power that may be brought under control and turned into useful ways from the streams of the state is unquestionably great, and is a problem of the utmost import to every community.

2. The demand for artesian waters, while not so widespread as in the states north and west, is yet urgent in many parts of Missouri. The desire for this source of water is not because the state is not well supplied with streams at the surface, nor because of unfavorable climatic influences, but by reason of the great convenience in the use of flowing wells, and on account of the common belief that such water is exceptionally pure. With the desire of securing flowing wells, borings have been put down in all parts of the state. In a large number of the cases failure has resulted. Why the efforts are not successful is marvelled at, since the principles involved in a successful artesian flow are so simple that it becomes to be generally believed that the governing conditions are equally simple, and all that is necessary is to put down a hole far enough and a flowing well will result. In reality the conditions of a successful flow are complex, and the practical determination of artesian areas involves a broad comprehension of the general geological features of the region, not of the state alone, but of the surrounding territory as well.

Considerable information has been obtained regarding the records of a large number of borings and deep wells and samples of the drillings or cores have been preserved whenever possible. When the theme is taken up and the work of collecting facts concerning the artesian probabilities for the various portions of the state is pushed vigorously, the data now constantly accumulating will form an invaluable foundation. Moreover, the collection of drill records adds vastly to a knowledge of the characters of the older and more deeply buried formations in Missouri, and discloses much of value in regard to their texture and structural relations.

3. The storage water and the well and spring waters are of particular importance. The former include those which are capable of being used in the same way as for irrigation. Although this method has not been demanded in this state there are nevertheless certain parts that suffer somewhat during the long dry spells that sometimes occur during the summer.

MISCELLANEOUS BRANCHES OF INQUIRY.

There are a number of branches of great economic importance which sooner or later will demand thorough investigation but at this time need only brief mention.

Prominent among them are natural gas and oil. The presence of the latter especially in noticeable quantities in many different parts of the state has awakened much interest in the possibilities of finding both of these substances in commercial quantities. With the recent discovery and extensive use of these substances in the neighboring provinces, the interest in the subject has been renewed and greatly intensified. Indeed, it may be truthfully said that during the past decade no geological question has occasioned more popular concern than that of likelihood of obtaining natural gas and petroleum within the limits of the state. In a number of places shallow borings have yielded, from time to time, sufficient quantities of natural gas for local use. The success of these small wells has led to the putting down of much deeper ones, and the expenditure of considerable amounts of money.

The excitement awakened by the discovery of oil and gas in Pennsylvania, Ohio and Indiana has stimulated still farther the efforts to secure them in Missouri. The general opinion has been, not only in this state, but in others as well, that the only prerequisite necessary to the securing of a successful flow of natural gas and oil is the sinking of a deep well. In reality the subject is much more complex than is commonly supposed. There are certain natural conditions, all of

which must be fully considered before a successful flow of either substance can be obtained. The absence of any one of these can only result in failure. The whole subject requires careful consideration.

Another industry is that of lime manufacture. Perhaps no state in the Union is better supplied than Missouri with limestone suitable for the manufacture of high grade of quicklime. Some localities are furnishing a quality of lime which may be regarded as having no superior in the world. Recent inquiry has shown that the lime industry is not developed near to the extent that it might be and that rocks well adapted to the manufacture of lime are more generally distributed than was supposed. In many places where lime was formerly burned, the industry could now be readily and profitably revived, as the circumstances which then militated against its continuance are now largely removed. Some special work in this direction has already been accomplished and two brief accounts published.

Closely associated with the lime manufacture is the making of cement. With the rapid development of the material prosperity of the state cements come to have a greater and greater importance each year. The term itself has recently come to be used in a much broader sense than formerly, and now applies to all those calcined lime products which will set or harden under water. Those grades which are capable of a more or less complete hardening are commonly called hydraulic limes, and are generally considered better than the ordinary varieties. Aside from the so-called hydraulic limestones which occur in various parts of the state, there are doubtless other materials which are capable of being made into a high grade of Portland or hydraulic cement. The investigations should determine the extent of the deposits, their composition and the methods of preparation.

Substances suitable for the manufacture of mineral paints are of more than local import.

The sands for glass-making and other purposes require careful discrimination. Glass-making has already become an important industry in the state, and the deposits should be accurately defined.

Marls for fertilizing purposes may in the future form valuable acquisitions to the mineral wealth of the state, though they may not be used at present. The extent and location of the deposits should be made known.

THE CABINET AND LIBRARY.

No material changes in the plan of the exhibits has been made since the cabinet was last reported upon. The collections made in pursuing the various lines of investigation are always divided into two classes.

One group is composed entirely of specimens obtained for purposes of study or analysis ; the other group is made up of specimens for exhibition in the cabinet.

A particular feature in this connection which deserves to be emphasized is the disposition of certain portions of the materials collected. In extending the usefulness of the work of the survey, special attention is now being paid to the selection of an educational series of specimens illustrative of the mineral resources of the state. As might naturally be expected, in connection with the minerals for the cabinet, there necessarily accumulates many duplicates which are not needed by the survey, after they have been studied and reported upon. Most of this material is of the greatest value for class instruction in colleges and high schools, and may be made available for this purpose at little or no additional expense to the survey. A number of educational institutions have already expressed a desire to obtain suites illustrative of the geology and economic resources of the state. In the case of the State university, installments of this kind have already been put up. Additional collections will shortly be made ready for other institutions in order of their applications.

As a further aid in college instruction, and as a special means of familiarizing the students with geographical phenomena of Missouri, a selected set of photographs pertaining to Missouri geology has been arranged for, and may be disposed of at the nominal cost of making the prints. This series will be added to continually, and will be made more and more complete as the work of the survey goes on. From the list of the photographs each instructor will be able to choose those objects he most desires.

The additions to the library have been numerous. Arrangements have been made with many of the organizations and societies having publications whereby exchanges may be made.

An important feature connected with this branch of the survey is the collection of the literature pertaining directly and indirectly to Missouri geology. Considerable progress has already been made. In this connection there has been prepared a complete bibliography of the literature relating to the state. It is in the form of a dictionary catalogue, with abundant cross-references and constitutes a part of volume X of the regular survey publications.

THE PUBLICATIONS OF THE GEOLOGICAL SURVEY.

A full explanation has already been made of the general plan adopted in the reports of the survey. In placing the results of the various investigations before the public progress at first was necessarily

slow. The reasons are obvious. Now that the survey is under good headway the reports on the various lines of work taken up will appear in more rapid succession than heretofore. Altogether there have been printed in the various reports about 5000 pages. The contents of the reports thus far published are as follows:

BIENNIAL ADMINISTRATIVE REPORTS.

225 Pages, 13 Plates, 6 Diagrams.

1. Biennial Report of the State Geologist, transmitted by the Bureau of Geology and Mines, to the Thirty-sixth General Assembly.
2. Biennial Report of the State Geologist, transmitted by the Bureau of Geology and Mines, to the Thirty-seventh General Assembly.
3. Biennial Report of the State Geologist, transmitted by the Bureau of Geology and Mines, to the Thirty-eighth General Assembly.
4. Biennial Report of the State Geologist, transmitted by the Bureau of Geology and Mines, to the Thirty-ninth General Assembly.

BULLETINS. (Series discontinued.)

470 Pages, 13 Plates, 11 Figures.

No. 1. Administrative Report; Coal Beds of Lafayette County; Building Stones and Clays of Iron, St. Francois and Madison counties; Preliminary Catalogue of Fossils occurring in Missouri.

No. 2. Bibliography of Geology of Missouri.

No. 3. Clay, Stone, Lime and Sand Industries of St. Louis City and County; Mineral Waters of Henry, St. Clair, Johnson and Benton Counties.

No. 4. Description of Lower Carboniferous Crinoids of Missouri.

No. 5. Age and Origin of the Crystalline Rocks of Missouri; Clays and Building Stones of Certain Western-Central Counties Tributary to Kansas City.

VOLUME I. PRELIMINARY REPORT ON COAL.

BY ARTHUR WINSLOW.

227 Pages, 1 Plate, 131 Figures.

CONTENTS:

Chapter I. Coal Measures.

Chapter II. Coal Beds.

Chapter III. Coal Industry.

Chapter IV. Systematic Description of Coal Beds.

Appendix A. Coal Mining in Thin Beds.

Appendix B. Coal Operators of Missouri.

VOLUME II. IRON ORES.

BY FRANK L. NASON.

366 Pages, 9 Plates, 62 Figures.

CONTENTS:

- Chapter I. Ores of Iron.
- Chapter II. Iron Ores of Missouri.
- Chapter III. Specular Ores of the Porphyry Region.
- Chapter IV. Red Hematites of Missouri.
- Chapter V. General Geology of the Ozark Uplift.
- Chapter VI. Specular Ores of Sandstone Region.
- Chapter VII. Limonite Ores.
- Chapter VIII. Introduction to Iron Ore Localities.
- Chapter IX. Specular Ores in Sandstone.
- Chapter X. Limonites.
- Chapter XI. Red Hematites.
- Appendix A. Iron Ore Deposits of Northeastern Arkansas.
- Appendix B. Historical and Statistical Sketch of Iron Industry.

VOLUME III. MINERAL WATERS.

BY PAUL SCHWEITZER.

256 Pages, 34 Plates, 11 Figures.

CONTENTS:

- Chapter I. Origin of Mineral Waters.
- Chapter II. Analysis and Composition of Mineral Waters.
- Chapter III. Therapeutics of Mineral Waters.
- Chapter IV. Mineral Waters of the State.
- Chapter V. Muratic Waters, or Brines.
- Chapter VI. Alkaline Waters.
- Chapter VII. Sulphatic Waters.
- Chapter VIII. Chalybeate Waters.
- Chapter IX. Sulphur Waters.
- Chapter X. European and Missouri Waters Compared.
- Appendix A. Relations between Grains per Litre and Grains per Gallon.
- Appendix B. Additional Analyses of Missouri Mineral Waters.
- Appendix C. Bibliography of Mineral Waters.

VOLUME IV. PALEONTOLOGY (PART I).

BY CHARLES ROLLIN KEYES.

314 Pages, 34 Plates, 9 Figures.

CONTENTS:

- Chapter I. Introduction.
- Chapter II. Sketch of Missouri Stratigraphy.
- Chapter III. Biological Relations of Fossils.
- Chapter IV. Protozoans and Sponges.
- Chapter V. Hydrozooids and Corals.
- Chapter VI. Echinoderms: Echinoids and Asteroids.
- Chapter VII. Echinoderms: Cystids and Blastoids.
- Chapter VIII. Echinoderms: Orinoids.
- Chapter IX. Worms and Crustaceans.
- Appendix. Stratigraphic Catalogue of Missouri Fossils.

VOLUME V. PALEONTOLOGY (PART II).

BY CHARLES ROLLIN KEYES.

320 Pages, 22 Plates, 2 Figures.

CONTENTS:

- Chapter X. Polyzoans.
- Chapter XI. Brachiopods.
- Chapter XII. Lamellibranchs.
- Chapter XIII. Gasteropods.
- Chapter XIV. Cephalopods.
- Chapter XV. Vertebrates.
- Appendix. Synonymic Indexical List of Fossils of Missouri.

VOLUME VI. LEAD AND ZINC DEPOSITS (SECTION 1).

BY ARTHUR WINSLOW.

387 Pages, 12 Plates, 71 Figures.

CONTENTS:

- Chapter I. Historical Sketch of Lead and Zinc.
- Chapter II. Lead and Zinc and their Compounds.
- Chapter III. Distribution and Conditions of Occurrence of Lead and Zinc.

- Chapter IV. Lead and Zinc Deposits of Foreign Countries.
- Chapter V. Lead and Zinc Deposits of the United States.
- Chapter VI. Industry and Statistics of Lead and Zinc.
- Chapter VII. History of Mining in Missouri.
- Chapter VIII. Physiography of the Mining districts.
- Chapter IX. General Geology.

VOLUME VII. LEAD AND ZINC DEPOSITS (SECTION II).

BY ARTHUR WINSLOW.

401 Pages, 28 Plates, 196 Figures.

CONTENTS:

- Chapter X. General Geology.
- Chapter XI. Geological History of Southern Missouri.
- Chapter XII. Ore Deposits.
- Chapter XIII. Industry and Statistics of Lead and Zinc.
- Chapter XIV. Mines of the Southwestern District.
- Chapter XV. Mines of the Southeastern District.
- Chapter XVI. Mines of the Central District.
- Appendix A Study of Cherts of Missouri, by E. O. Hovey.
- Appendix B. Methods of Analysis, by J. D. Robertson.
- Appendix C. List of References.

VOLUME VIII. ANNUAL REPORT, FOR 1895.

BY CHARLES ROLLIN KEYES.

406 Pages, 30 Plates, 16 Figures..

CONTENTS:

1. Organization and Results of a State Geological Survey, by Charles Rollin Keyes.
2. Crystalline Rocks of Missouri, by Erasmus Haworth.
3. Dictionary of Altitudes, by Curtis Fletcher Marbut.
4. Characteristics of the Ozark Mountains, by Charles Rollin Keyes.
5. Coal Measures of Missouri, by Garland C. Broadhead.

VOLUME IX. AREAL GEOLOGY.

432 Pages, 4 Folio Maps, 25 Plates, 53 Figures.

CONTENTS:

1. Areal Geology and its Relations to other Geological Work, by Charles Rollin Keyes.

2. Report on the Higginsville Sheet, in Lafayette county, by Arthur Winslow.
3. Report on the Bevier Sheet, including portions of Macon, Randolph and Chariton counties, by C. H. Gordon.
4. Report on the Iron Mountain Sheet, including portions of Iron, St. Francois and Madison counties, by Arthur Winslow, Erasmus Haworth and Frank L. Nason.
5. Report on the Mine la Motte Sheet, including portions of Madison, St. Francois and Ste. Genevieve counties, by Charles Rollin Keyes.

VOLUME X. SURFACE FEATURES.

534 Pages, 22 Plates, 24 Figures.

CONTENTS :

1. Physical Features of Missouri, by Curtis Fletcher Marbut.
2. Formation of Quaternary Deposits, by James E. Todd.
3. Bibliography of Missouri Geology, by Charles Rollin Keyes.

VOLUME XI. CLAY DEPOSITS.

BY H. A. WHEELER.

622 Pages, 39 Plates, 15 Figures.

CONTENTS :

- Chapter I. Introductory.
- Chapter II. Geological Occurrence of Clays.
- Chapter III. Chemical Properties.
- Chapter IV. Physical Properties.
- Chapter V. Plasticity.
- Chapter VI. Shrinkage.
- Chapter VII. Fusibility.
- Chapter VIII. China-ware Clays.
- Chapter IX. Flint fireclays.
- Chapter X. Plastic fireclays and Firebrick Industry.
- Chapter XI. Potters' or Stoneware Clay and the Stoneware Industry.
- Chapter XII. Shales of Missouri.
- Chapter XIII. Terra Cotta, Roofing-tile, Sewerpipe, Draintile and Flower-pot Clays and Industries.
- Chapter XIV. Paving-brick Clays and Industry.
- Chapter XV. Building Brick Clays and Industry.
- Chapter XVI. Burnt Ballast Clays and Industry.

Chapter XVII. Prospecting for Clays.

Chapter XVIII. Sampling and Analyzing Clays.

Chapter XIX. Tables of Tests and Analyses.

Chapter XX. Bibliography.

VOLUME XII. AREAL GEOLOGY. (In Press.)

BY CURTIS FLETCHER MARBUT.

400 Pages, 5 Folio Maps, — Plates, — Figures.

CONTENTS.

1. Geology of the Clinton Sheet, in Henry County.
2. Geology of the Calhoun Sheet, in Henry county.
3. Geology of the Lexington Sheet, Lafayette and Ray Counties.
4. Geology of the Richmond Sheet, in Ray and Carroll Counties.
5. Geology of the Huntsville Sheet, in Randolph, Chariton and Howard Counties.

INDIVIDUAL WORK OF THE GEOLOGICAL CORPS.

More than ever before the energies of the geological survey have been directed, during the biennial term, towards the preparation of material for proper presentation to the public. The larger portion of the efforts has been to bring together the data already obtained rather than to collect it. This has been necessary in order to concentrate the work on a few branches at a time that they may be hastened towards completion and the results made public. Otherwise it would be necessary to scatter the energies over many lines with the result of only doing a little every year on each. The beneficial effects of this concentration of effort is readily seen in the reports which have been prepared and printed.

The time of the state geologist has been very fully occupied. Aside from the numberless details connected with the necessary administrative duties, which are not only multifarious and imperative, but very largely unproductive and unassignable to others, there has been an unusually large amount of editing and revising of manuscripts, proof-reading, superintendence of the drawing of maps and cuts, and the preparation of other illustrations. The five volumes amply attest the activities in this direction.

In the field the work of the state geologist has been somewhat varied. Widely unrelated as these investigations may appear at first glance they have always had in view the accomplishment of one of three themes upon which personal attention has been chiefly concen-

trated. The first of these has to do with the collection of data for a report on the coal deposits of the state; the second deals with the order and age, structure and distribution of the formations of the Ozark region, with special reference to the origin, concentration and distribution of the ore deposits; and the third has been to secure facts regarding the areal distribution of the different geological formations for the purpose of preparing a geological map of the state that is better than the preliminary one that has been used for some years.

1. In the work on the coal deposits a number of features have received special consideration. On the whole, attention has been directed more particularly towards the solution of the more general problems connected with the classification of the deposits; the means of correlating the different parts, and the boundaries of the main subdivisions of the Carboniferous. The results have been eminently satisfactory. Several summaries on different phases of the inquiries have already been given to scientific journals. Among those which should be mentioned are: (a) The determination of the base of the Carboniferous of the region, which was found to be much higher than was generally regarded, being at the base of the Chouteau limestone instead of the Louisiana, thus placing two whole formations, the Louisiana limestone and the Hannibal shales, into the Devonian instead of the Carboniferous, (b) the satisfactory separation of the Carboniferous system into four series, each of which is distinctly defined and clearly traceable throughout the range of the Western Interior basin, the productive coal measures constituting the second series from the bottom, (c) the formulation of criteria for stratigraphic correlation has been of great practical use, the principles suggested not only having reference to the coal-bearing strata, but being of much wider application, (d) the recognition of several minor subdivisions of the coal-bearing strata is important inasmuch as the subdivisions are now easily made out.

2. This work on the Ozark region has been chiefly in the crystalline region of the Southeast where good progress was made in determining the structure and arrangement of the strata of that region about which little definite information had been previously known. Among the principal points determined there may be noted: (a) the probable reference of the granites to the Algonkian instead of to the Archæan as heretofore, (b) the proper superposition and relations of the formations forming the base of the sedimentaries around the old crystalline peaks, (c) the relations of the porphyries to the granites, and (d) a probable solution to the deposition of the ore deposits of the southeast.

3. In the collection of data for the rectifying of the present preliminary geological map of the state, much has been accomplished. Mr. Marbut's share in this line is given in detail farther on. Aside from the work in the northwest and southwest already referred to some time was spent along the great Oap an Gres fault in eastern Missouri, which causes some very anomalous features in the surface distribution of the formations. Some similar though less profound dislocations were also examined in the southeast.

Some time was also spent in finishing up the field work on the Mine la Motte sheet and also on the Bonne Terre sheet.

In the more productive work of collating the results of the investigations which were made in the field there are: (a) the report on the Mine la Motte sheet, (b) the bibliography of Missouri geology in the form of a dictionary catalogue of over 300 pages, (c) the chapter of the geology of Missouri clays to accompany Mr. Wheeler's report, and (d) several minor papers. These have already been printed. Of the matter not printed about 300 pages have been written on the coal report and 200 pages on the Ozark region. In addition, a dozen briefer papers announcing important results were sent to the scientific journals, and about the same number on more strictly economic themes have appeared in the trade and engineering journals. Many articles have also been furnished the principal newspapers of the state and these have been reprinted entire or in part by many others.

Prof. C. F. Marbut has been engaged on a variety of inquiries all however, directed toward one main theme. In the field he has completed the mapping of several areas in the western part of the state. He has also been tracing the geological boundaries in the southwestern, southcentral and southeastern parts of the state, the result of which has been to greatly increase our exact knowledge of the geology of south Missouri. Among the facts brought out may be mentioned (a) the determination of the areal distribution of some of the principal formations occurring on the crest of the Ozark dome, (b) the fixing of the geological age, by finding large and characteristic fossils, of a large part of the western half of the dome in Missouri, which taken in connection with the results obtained in the crystalline region point to the fact that a large part of the surface of the uplift is occupied by Ordovician rocks while a very considerable area around the granite district is Cambrian in age, (c) the noting of some minor domes on the general surface of the great Ozark uplift, which give important peculiarities to the areal distribution of the geological formations which were previously inexplicable.

In the preparations made for publication Mr. Marbut has made a final revision of the Dictionary of Altitudes, which is now printed as a part of volume VIII of the regular series of reports of the survey. It is essentially a list of elevations of all the towns, in which all figures of altitudes are reduced to mean sea-level as a datum plane, though the lines of precise levels run under Federal auspices. Differences as much as 50 feet were found in some cases. Another important work which has been finished and printed is a study of the origin of the Surface Features of the state in accordance with modern geographic principles. Mr. Marbut is especially well fitted for this branch of work which was begun at Harvard university at the suggestion of Prof. W. M. Davis, and carried on largely under the latter's direction. The work is not only an aid to the geological investigations to be carried on but it is of great value as providing local data for the teaching of geography in our common schools, the method of which have so recently undergone such a complete revolution. The facts incorporated and the principles enumerated are in strict harmony with the new methods of instruction. The Missouri part of a new geography which is to be largely used in the schools in the state has already been entirely rewritten in accordance with the statements set forth in this report.

He has also entirely revised and partly rewritten five areal reports; these are the Olinton, Calhoun, Lexington, Richmond and Huntsville sheets. They will constitute volume XII of the regular series. The accompanying topographic and geologic maps have also been finished up and the geological cross-sections have been constructed and drawn.

Prof. H. A. Wheeler has completed the preparation of his report on the Clay Deposits. The field and laboratory work were completed in the previous biennial period, and several chapters of the report written. The report is a bulky one of more than 600 pages, illustrated by about 40 plates, several maps and cuts. It is divided into 20 chapters in which the various phases of the subject are treated thoroughly, the whole forming a well balanced and symmetrical treatise.

The results of the physical tests of the clays are especially noteworthy, and open a broad field of work in the practical study of clays that is rarely accomplished by the ordinary methods adopted. The extent and variety of clay deposits that are suitable for the manufacture of nearly every kind of clay-ware, from the common brick to china, has been shown by this recent investigation to far surpass all estimates previously made and to exceed greatly the most sanguine expectations. The practical testing of the characters and composition of the white

clays of southeast Missouri has shown that they form an excellent grade of material that is admirably adapted for making china ware. The deposits of this character are destined in the near future to assume great importance when their purity and extent are better known. Two general classes of china clays are known. The ball clay and kaolin. The former is used for the body of the white ware and is the bonding material with which feldspar, flint and kaolin are mixed to make up the constituents of china ware. Extensive deposits are known and it is already being shipped to East Liverpool and other pottery centers. The kaolins are the less plastic china clays and also exist in extensive beds. The deposits of china clays are so extensive the conditions for obtaining the other materials used in the manufacture of china ware so favorable, and the facilities for transportation so good that with proper inducements Missouri should be the largest pottery center in the country. The advantages offered for the development of this industry alone is certain to attract capital sufficient to start up, on an extensive scale, a new industry for the state.

Mr. E. H. Lonsdale, during the six months that he was connected with the survey, was engaged chiefly in areal work and the investigation of building materials. In the field, four weeks were spent in the granite region of southeast Missouri. Much of this time was spent in obtaining notes on the economic products of the Mine la Motte area, and particularly in noting the building stones. The topographic map of this region was finished, and a number of drawings for the text prepared. In addition to the various other duties which he undertook he wrote out the notes he had obtained in the Mine la Motte district.

Mr. T. B. Marbut was engaged in the preparation of the maps and illustrations for the report on clay, and for several sheet reports. Having assisted in the field work on several of the areas he was especially well fitted for finishing up the topographic sheets ready for the engraver. A number of drawings for plates were also made for four volumes of reports, and the necessary sketches for the cuts.

Mr. R. R. Rowley has spent some time during the past summer in mapping the geological formations of a part of Pike county. This is a continuation of similar work already begun in the same region. As the range of formations is very extended for an area of the size of this one, from the Lower Silurian or Ordovician through the Upper Silurian and lower Carboniferous to the coal measures, and as the conditions of erosion are such as to enable the relations to be made out with great detail, the region is of much more than ordinary interest, not only scientifically but economically, for it furnishes the key to the exact arrangement and succession of the different beds in a large part of

eastern Missouri. Moreover, this is the locality in which recently the base of the Carboniferous series was for the first time definitely determined in the Mississippi basin. On account of the importance of this determination, as one of the results of this work, there has been prepared a special paper on this subject in which Mr. Rowley is joint author.

Miss E. L. Carter has efficiently acted as stenographer and copiest throughout the biennial term.

Mr. J. D. Robertson was employed for a period of four months in assisting Mr. Wheeler in the preparation of the report on clay, chiefly in the construction of statistical tables and in writing certain sections with which he was more or less familiar, having previously made the analyses and collected the data.

Prof. J. E. Todd has prepared the manuscript of his report on the surface deposits of the northern half of the state and the results constitute part second of volume x of the regular Survey series of publications. The field work had been done two years previous. The results of this work are especially suggestive.

EXPENDITURES DURING THE BIENNIAL PERIOD.

During the past biennial period the appropriation for the continuance of the Survey has been the same as it was during the previous term. A tabulated statement showing the distribution of the funds is given below :

Salaries	\$8,015 50
Subsistence.....	299 75
Railway fares.....	430 52
Horse and wagon hire.....	187 75
Postage and telegrams	149 13
Freight and express.....	469 52
Office supplies and furniture	199 00
Laboratory supplies and instruments.	6 55
Field instruments and supplies.	75
Library, books.....	52 92
Photographs and supplies.....	98 00
Reports, printing.	2,492 27
Reports, binding	3,536 10
Maps	1,188 10
Plates	838 85
Figures, drawing, etc.....	52 73
Office printing	78 37
Temporary assistance.	1,909 08
Balance	11
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